1951.

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

THIRD ANNUAL REPORT

OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR THE

YEAR ENDING 30TH JUNE, 1951.

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COMMONWEALTH OF AUSTRALIA.

Commonwealth Scientific and Industrial Research Organization.

THIRD ANNUAL REPORT FOR THE YEAR ENDING 30TH JUNE, 1951.

I. INTRODUCTORY.

1. General.

The Commonwealth Scientific and Industrial Research Organization was established on 19th May, 1949, when the *Science and Industry Research Act* 1949 was proclaimed. Under that act the Organization took the place of the existing Council for Scientific and Industrial Research, which in turn had in 1926 taken the place of the former Institute of Science and Industry.

The powers and functions of the Organization are similar to those of the Council and include the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth or any territory of the Commonwealth, or in connexion with any matter referred to the Organization by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; the publication of scientific and technical reports and periodicals; and acting as a means of liaison with other countries in matters of scientific research.

2. Advisory Council.

During the past year Sir David Rivett resigned from the chairmanship of the Advisory Council, but remains a member of that body. Dr. I. Clunies Ross was appointed in his stead. Mr. A. J. Gibson and Mr. C. Euston Young resigned from the Council, and the Honorable O. McL. Falkiner, M.L.C., and Mr. W. A. Gunn were co-opted as members. Professor J. P. Baxter was appointed Chairman of the New South Wales State Committee.

3. Retirement of Dr. B. T. Dickson and Mr. A. V. Lyon.

Dr. B. T. Dickson retired from the position of Chief of the Division of Plant Industry in May, 1951, after 23 years of service. He came to Australia from Canada in 1927 and was the first Chief of the Division. Under his leadership it grew into a major research institute with head-quarters at Canberra and branch laboratories and field stations at many points throughout Australia, including Brisbane, Armidale, Deniliquin, and Perth.

Mr. A. V. Lyon, Officer-in-charge of the Commonwealth Research Station, Merbein, retired early in 1951. He had been Officer-in-charge of the Station since its formation in 1919, and under his direction an impressive record of research into problems of the viticultural and other industries in the Murray Irrigation Areas was built up. The work developed in close association with the growers and the results have at all times been rapidly put into practice to increase production and improve products. Mr. Lyon has been succeeded as Officer-in-charge by Mr. F. Penman, formerly Chief Irrigation Officer of the State Rivers and Water Supply Commission of Victoria.

4. Land Research and Regional Survey Section.

During the past year the Land Research and Regional Survey Section has been split off from the Division of Plant Industry as an independent Section. Its functions include, firstly, the conduct of regional surveys of the agricultural and pastoral possibilities of undeveloped areas of north Australia and, secondly, agricultural research at Kimberley Research Station, Western Australia, Katherine Research Station, Northern Territory, and the Ayr State Regional Experiment Station, Queensland. The Section is under the leadership of Mr. C. S. Christian.

5. Agricultural Research Liaison Section.

The Agricultural Research Liaison Section was established at Head Office during the past year to assist in making the Organization's results in agricultural research speedily available to State Departments of Agriculture for use in their extension work. The Section is under the leadership of Mr. R. R. Pennefather.

6. Development of Northern Australia.

The Organization has continued its interest in problems relating to the development of northern Australia. The Land Research and Regional Survey Section has completed a survey of the Burdekin Valley and adjacent country in the Townsville-Bowen region of Queensland to provide information to departments concerned with examining proposals to dam the Burdekin River and irrigate country in the lower Burdekin Valley.

At the Katherine Research Station, Northern Territory, problems of dry-land agriculture on the lighter-textured soils in the dry monsoon belt of northern Australia are under investigation. Problems of irrigated agriculture on the heavy-textured soils of this belt are being examined at the Kimberley Research Station, Western Australia, in collaboration with the Western Australian Department of Agriculture. The Organization is also co-operating in investigations on irrigated tropical pastures at the Ayr State Regional Experiment Station, Queensland. It is represented on committees established by the Department of Territories to investigate proposals for the establishment of a rice research station in the Northern Territory and a demonstration farm in the "Tipperary" lands of that area.

7. External Territories.

Under the new act, the Organization is charged with responsibility for research of interest to primary and secondary industries not only of the Commonwealth, but also of Australia's external territories. During the year the Organization's officers have, when requested, provided technical advice to the Administration of Papua-New Guinea. Arrangements have been made to establish a survey unit as part of the Land Research and Regional Survey Section to undertake a long-term survey of lands in Papua and New Guinea.

8. Wool Production and Textile Research.

The major activities associated with the programme of biological research in the field of wool production are reported in Chapter VII. This work is carried out mainly in the Divisions of Animal Health and Production, Biochemistry and General Nutrition, and Plant Industry.

Research on wool textiles is reviewed in Chapter XV. Progress has been made in staffing and equipping the three wool textile research laboratories in Melbourne, Sydney and Geelong, and the co-ordination of their activities by the Wool Textile Research Committee is working smoothly.

9. Myxomatosis in Rabbits.

Considerable success has attended the Organization's experiments on the use of the virus disease, myxomatosis, against the rabbit. These experiments have been conducted as part of the programme of research of the Wildlife Survey Section.

During the past season the disease, which is harmful only to the rabbit, spread from a test site near Corowa, New South Wales, to cover in patchy fashion an area embracing the Murray River system and extending for nearly 1,000 miles from east to west and from north to south. It is difficult to form any reliable estimate of the number of rabbits killed, but reports have been received that properties of up to 100,000 acres have been cleared. In most cases, however, the kills have been confined to areas fringing river frontages, except in the north, where activity has been more widespread.

It is known that mosquitoes and other blood-sucking insects have played a major part in distributing the virus throughout the rabbit population. Many aspects of the mechanism of the transmission remain unexplained, however, and plans are now in hand for investigations designed specifically to elucidate doubtful points.

10. Plant and Animal Genetics.

The Executive has for some time past been examining the possibility of strengthening the work being done in Australia in genetics.

The lack of facilities for post-graduate training and research in plant genetics has for many years been keenly felt by a number of interested bodies, and increasing difficulty has been experienced in obtaining adequately trained staff for work in this field. A Chair of Genetics has been established in the University of Adelaide as a result of a grant made by the Organization. In addition to his University duties, the professor will act as a consultant and adviser to the Organization on its work in genetics and plant breeding. Dr. D. G. Catcheside, M.A., D.Sc., F.R.S., formerly Reader in Plant Genetics, University of Cambridge, has been appointed to the position.

Arrangements have also been made with the University of Sydney for a co-operative scheme in which the Organization will appoint two animal geneticists and the University will provide laboratory, office, and small-animal accommodation. In addition to undertaking research, the officers will carry out such teaching or supervision of post-graduate research students as may be necessary for the development of higher training in animal genetics within the University.

11. Building Projects.

The Organization still faces great difficulties in developing its research programme owing to the lack of suitable buildings and the extremely slow rate at which they can be provided. Many Divisions have to carry on their work under crowded and difficult conditions, and proposed new research programmes are held up by lack of accommodation. A start has been made on the Wool Biology Laboratory at Prospect, New South Wales, on a central block at Canberra to provide a library, controlled temperature and humidity rooms, and other facilities for the Divisions of Plant Industry and Entomology, and on the Wool Textile Research Laboratory at Geelong. Further progress has been made on the laboratory building for the Division of Tribophysics in the grounds of the University of Melbourne. Another major building project contemplated is a dairy research block at Highett, Victoria.

12. Overseas Conferences.

A number of important scientific conferences attended by officers of the Organization included the Fifth International Congress for Microbiology, Rio de Janeiro; Fourth International Congress of Soil Science, Amsterdam; British Commonwealth Specialist Conference on Fuel Research, London; International Conference on Coal Preparation, London; International Building Documentation Conference, Paris; Pan Indian Ocean Science Congress, Bangalore; Forestry and Forest Products Commission for Asia and the Pacific Conference, Bangkok; International Symposium on Atmospheric Turbulence, Massachusetts; Meeting of International Union of Radio Science, Zurich; International Astronomical Union Conference, Brussels; Ionospheric Conference, Pennsylvania; General Assembly of International Union of Geodesy and Geophysics, Brussels; Twelfth Meeting of International Commission on Illumination, Stockholm.

13. Technical Assistance to South-East Asia.

Continued assistance was afforded to the Department of External Affairs, which is administering the Australian contribution to the Colombo Plan for providing technical assistance to South-East Asia. The Organization's main part is in affording laboratory and field experience to research workers from the various South-East Asian countries. Such visitors are now being accommodated in the various Divisions and Sections in increasing numbers. Up to date, the main demand has been for experience in the fields of forest products, radio research, food preservation, and fisheries.

14. Studentships and Overseas Visits.

During the year under review, nineteen officers of the Organization were sent overseas for some months to collect information on new developments in scientific research and to acquire general experience in research and training in new techniques.

Mr. C. M. Donald, Senior Agrostologist, Division of Plant Industry, was selected to join a small team investigating the grassland problems of the Mediterranean area for the Sub-Committee on Agricultural Technology of the Organization for European Economic Co-operation. Mr. I. S. R. Munro, of the Division of Fisheries, visited Ceylon for some months under the Colombo Plan to advise the Cingalese Government on its fisheries research programme. Two officers were seconded for work with the F.A.O.:—Mr. A. B. Cashmore as Range Manager and Specialist in Cyprus, and Mr. F. Skaller to advise the Government of Pakistan on poultry breeding problems.

In addition, more recent graduates were awarded studentships and traineeships for training in fields which would enable them to fill specific posts in the Organization on completion of their training. Twenty studentships and traineeships were awarded from general C.S.I.R.O. funds, five studentships for work on wool, and one from S.I.E.F. moneys. At the close of the year 32 holders of studentships awarded in

previous years were receiving training in the United Kingdom, the United States of America, Canada, and Australia.

15. Research Associations.

The Organization has continued to support the Australian Leather Research Association. This body, which has the legal form of a non-profit-making company registered under the New South Wales Companies Act, is similar to the research associations operating in Great Britain under the aegis of the Department of Scientific and Industrial Research. Representatives of several other industries are discussing with the Organization the possibility of establishing research associations.

16. Collaboration with Universities.

The Organization gratefully acknowledges its debt to the various Australian universities, with which it works in close collaboration. The establishment of research units within the universities is of great importance as it enables the Organization's officers to enjoy the stimulus and help of authorities in different fields of science. The Organization's work in the various universities has now grown considerably and is mentioned in various places in the main body of this Report.

17. Science and Industry Endowment Fund.

During the year the Executive, as Trustees of the Science and Industry Endowment Fund, made grants to assist research workers as follows:—Mr. J. M. Black, for revision of his publication on the flora of South Australia; Dr. B. Breyer, in connexion with polarographic investigations; Dr. E. B. Brown, for the development of a new recording system for moving coil electric gauges; Mr. F. W. Hely, to assist him in undertaking research on soil fertility at the College of Agriculture, Madison, United States of America, under a Farrer Memorial Scholarship; Professor G. E. Nicholls, for studies of Tasmanian freshwater fauna; Dr. J. Pearson, for work on comparative anatomy and embryology of marsupials; Mr. Tarlton Rayment, for taxonomic work on bees; Dr. E. J. Reye, for studies of Ceratopogonidae (sand flies); Mr. A. Robertson, for ornithological investigations; and Major H. M. Whittell, to gather material for a bibliography of Australian ornithology.

In addition, a studentship for overseas training was awarded to Miss S. Duigan for work on pollen morphology at the University of Cambridge.

18. Finance.

Chapter XXXV. gives details of expenditure during 1950-51 by the Organization totalling £3,086,364. This amount includes a total of £507,320 derived other than direct from the Commonwealth Treasury, including £82,609 expended from the Wool Industry Fund and £329,633 expended on wool production and wool textile research from funds derived from the Wool Research Trust Account established under the provisions of the *Wool Use Promotion Act* 1945. Certain other expenditure involved in erection costs of buildings was also incurred on behalf of the Organization.

The Organization is particularly gratified by the way in which outside bodies continue to support it, and by the marked interest evinced by certain sections of industry which have provided donations for co-operative research. Among the many contributions received, reference may be made to those of the Commonwealth Bank, Australian Wool Board, Australian Meat Board, Australian Dairy Produce Board, and Australian Wine Board, the Queensland Government and Queensland Meat Industry Board, the New South Wales Department of Agriculture and New South Wales Water Conservation and Irrigation Commission, the Victorian Railways, the George Aitken Pastoral Research Trust, Burdekin Bequest, Ian McMaster Bequest, and Alexander Fraser Memorial Fund, the Dried Fruits Control Board and the dried fruits industry, the National Gas Association, Australasian Institute of Mining and Metallurgy, Australian Cement Manufacturers' Association, the wool textile industry, the timber industry, and the pulp and paper industry.

A statement has been included of expenditure on contributions made by the Commonwealth to the Commonwealth Agricultural Bureaux, and the establishment and maintenance of the Chair of Aeronautics at the University of Sydney, and on grants to the Standards Association of Australia, the Australian National Research Council, and the National Association of Testing Authorities. The Organization is responsible for the administration of the funds expended in this way.

19. Organization.

For the purpose of carrying out its research work the Organization has established a number of Divisions and Sections. The Divisions, of which there are now fifteen, comprise the major establishments, which may be further subdivided into Sections; there are also independent Sections comprising establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions.

In the present Report an attempt has been made to group the material according to its subject matter rather than according to the Division or Section concerned. Additional chapters and appropriate cross references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbonrne and associated with it are the Organization's Information Service, Central Library, Agricultural Research Liaison Section, and Central Experimental Workshops.

The Divisions which have been established (in order of their formation) are as follows:—

Plant Industry, with head-quarters and main laboratories at Canberra and field stations and experiment farms at Canberra, Australian Capital Territory, Lawes and Stanthorpe, Queensland, Trangie, New South Wales, and Kojonup, Western Australia.

Entomology, with head-quarters and main laboratories at Canberra and field stations at Bright, Victoria, Trangie, New South Wales, and Rockhampton, Queensland.

Animal Health and Production, with head-quarters in Melbourne and main laboratories in Melbourne and Sydney, a branch laboratory at Yeerongpilly, Queensland, and field stations at Badgery's Creek and Barooga, New South Wales, Cunnamulla, Queensland, and Werribee, Tooradin, Cobram, and Coleraine, Victoria.

Biochemistry and General Nutrition, with head-quarters at Adelaide and field stations at O'Halloran Hill, Robe, and Brecon, South Australia.

Soils, with head-quarters and laboratories at Adelaide.

Forest Products, in Melbourne.

Food Preservation and Transport, with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane, and minor laboratories at Gosford, New South Wales.

Fisheries, with head-quarters and main laboratories at Cronulla, New South Wales, laboratories in Perth and Melbourne, and field stations at Brisbane, Hobart, and Thursday Island.

Metrology, Physics, and Electrotechnology, comprising together the National Standards Laboratory, Sydney.

Radiophysics, at Sydney.

Industrial Chemistry, with head-quarters and main laboratories in Melbourne and branch laboratories in Sydney, Adelaide, and Perth.

Tribophysics, in Melbourne.

Building Research, in Melbourne.

The following are the Sections:—

Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria.

Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales.

Radio Research Board, with head-quarters in Sydney and branch laboratories in Brisbane and Canberra.

Flax Research, Melbourne.

Ore-dressing Investigations, Melbourne and Kalgoorlie, Western Australia.

Mineragraphic Investigations, Melbourne.

Mathematical Statistics, Adelaide.

Dairy Research, Melbourne.

Meteorological Physics, Melbourne.

Coal Research, Sydney.

Wildlife Survey, with head-quarters in Canberra and field station at Albury, New South Wales.

Mathematical Instruments, Sydney.

Wool Textile Research Laboratories, with head-quarters in Melbourne and additional units in Sydney and Geelong, Victoria.

Land Research and Regional Survey, with head-quarters in Canberra and field stations at Ayr, Queensland, Katherine, Northern Territory, and Ivanhoe (Kimberley), Western Australia.

In addition, Regional Centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular district) have been established as follows:—

Regional Pastoral Laboratory, Deniliquin, New South Wales, with its associated Falkiner Memorial Field Station.

Regional Pastoral Laboratory, Armidale, New South Wales, with its associated field station, "Chiswick".

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

Plant and Soils Laboratory, Brisbane.

II. SOILS.

1. General.

The Division of Soils is concerned with research into the classification, properties, and problems of Australian soils of both an applied and a fundamental nature. The Division is the central and main body engaged in soil research in Australia, taking part either actively or consultatively in the very great bulk of investigations in this field. The primary objectives may be summarized under four headings:—

(i) The systematic mapping of the soils of Australia in broad categories as an evaluation of national soil resources and as a comparative survey relating pedologically the soil groups of this and other countries.

(ii) The classification and mapping in varying degrees of detail of the soils of specific areas in regions marked for future or more intensive settlement or in which problems of production have arisen; this is a service of immediate value to the farmer and to the State advisory and administrative bodies.

(iii) Applied research into problems concerning soil fertility or other chemical or physical factors affecting productivity.

(iv) Fundamental research on the pedology, chemistry, physics, and microbiology of Australian soils. This is becoming an increasingly important activity on which depends the progress of applied research in the Division as well as investigations of other Divisions and outside agricultural authorities.

Work at the Commonwealth Research Station, Merbein, Victoria, and the Irrigation Research Station, Griffith, New South Wales, on soils and their behaviour under irrigation is described in Chapter IV., Sections 2 and 3.

Division of Soils.—The Division of Soils operates in four closely linked sections—pedology and soil survey, soil chemistry, soil physics, and soil microbiology. The work described in this Chapter is decentralized into five regional centres outside headquarters in Adelaide, namely, Brisbane, Canberra, Deniliquin, Perth, and Hobart. At three of these, Brisbane, Perth, and Hobart, branch laboratories are already in existence, and it is proposed to add a further large unit at Canberra. The object of decentralization is for the more effective control of the widespread soil investigations and better administration in regional units of a more self-contained character. The development of the branch laboratories is relieving the pressure of analytical work at headquarters and allowing a closer relationship of field and laboratory workers on regional problems. It is proposed to establish a balanced team at each main centre and the first of these is now operating in Brisbane.

For many years the Division has been interested in the relationships of soils and land use. Considerable knowledge has been gained from work over the past 24 years in irrigation areas, and this has crystallized in a system of land classification accepted by settlement and irrigation authorities in the several States. More attention is also being paid to this subject in developmental proposals in new country which is being opened up for the settlement of ex-servicemen. It is felt that much of the Division's survey work is made useful only through such further studies which build on the collected basic soil data. One aspect of this is the study in suburban areas of soils in relation to engineering properties and building foundations. The classification, mapping, and characterization of the major soils of Melbourne and Adelaide, particularly in regard to seasonal changes in moisture content, have provided the first sound information for the investigations. The Commonwealth and State authorities concerned with building research and mass construction of houses have been closely associated with the soil mechanics work of the Division.

The Division has co-operated continuously with the Waite Agricultural Institute, University of Adelaide, where the main head-quarters laboratories are located, and has kept in touch with State and Commonwealth bodies interested in the research programme.

During the year, four officers have been overseas either working in British laboratories or conferring with research workers at various centres in Europe, America, and India on subjects within their special fields. The Division represented the Organization at the Fourth International Congress of Soil Science in Holland in July, 1950, and supplied a delegate to the Pan Indian Ocean Science Congress in India in

January, 1951. The Division also represents Australia on the Commission on Soil Genesis and Classification set up by the International Society of Soil Science.

2. Soil Survey and Pedology Section.

Work in the Soil Survey and Pedology Section for the past year comprised both routine soil surveys and fundamental pedological investigations. Staffing problems, including the loss of some experienced surveyors during the year, continue to limit the number of projects undertaken, and many requests for assistance from outside authorities could not be met. Nevertheless, work has proceeded on a total of 15 surveys throughout the Commonwealth, covering areas from 4 to 80,000 square miles. Compilation of a manual of Australian soils, for identification of Great Soil Groups as they occur in Australia, was begun last year and is nearing completion. This manual is designed for use by officers of numerous authorities interested in soils for agricultural, forestry, engineering, and irrigation purposes.

(*a*) *South Australia.*—Survey of a third area for settlement of ex-servicemen on Kangaroo Island was completed, making a total of 250,000 acres mapped and classified. The routine work of land classification and subdivision on Kangaroo Island is now in the hands of the State authorities, the Division of Soils retaining an advisory interest. Despite the known deficiencies hindering production and the low degree of fertility of soils, the greater part of the surveyed area appears satisfactory for development in sufficiently large units.

A detailed survey of the Cooltong division of the Chaffey Irrigation Area, for the purpose of extending existing horticultural settlements, has been completed. Only portion of it was found suitable for planting, making any considerable extension impracticable.

Detailed study of the soils of the Barossa Valley has been continued. This region is providing an instructive study in diverse problems of soil formation, soil-plant relationships for a comprehensive range of horticultural crops under dry-land conditions, economic land use, and soil conservation. Field work is about half completed and will be continued during the coming year.

The reconnaissance survey of an area of 230 square miles being considered for additional drainage and intensified settlement in the Kingston-Lucindale district in the south-east of the State has been completed. Considerable problems in drainage control, salinity, and soil infertility face development of this area. The survey defined the soils and associated land-use relationship. The field party has since moved northward to County Buckingham, where a reconnaissance over an area of some 400 square miles has been begun. This survey has in view the need of assisting current early stage settlement by enabling a discriminating choice of the various sorts of soils to be made. Such a choice is essential if the risk of wind erosion and of settlement on soils not yet proved suitable for pastures is to be avoided.

(*b*) *Victoria.*—A soil survey of the Preston suburban area of Melbourne was carried out on behalf of the Victorian Housing Commission.

(*c*) *New South Wales and Australian Capital Territory.*—Reports on surveys of areas at Nyngan and Narromine in the Macquarie region have been issued and plans are in hand for a third area near Warren to be similarly investigated. The surveys are aimed at determining the relative merits of irrigation development for different crops of areas commandable from the Macquarie and Bogan Rivers for which limited supplies of water are to be available.

The broad reconnaissance of the soils of the irrigation zone of south-eastern Australia has progressed. It is in abeyance for a short time during the absence of the supervising survey officer on a study tour overseas. The Division has handled an ever-increasing demand for information and maps, from local and State authorities in this and other regions.

A survey of the southern tablelands region, as a basis for pasture development and animal husbandry, has been commenced and will eventually embrace some 7,500 square miles of comparatively rich country. This work has been held up in previous years by the more pressing demands of the survey of the Macquarie region. At present about 1,250 square miles in the north of the region have been mapped.

Detailed surveys, including examination of the erosion status, have been made over the northern portion of the Australian Capital Territory, comprising about 400 square miles. This work was carried out at the immediate request of the Department of the Interior, which is charged with soil conservation in the Territory, but it has also brought to light interesting pedological features. The remainder of the Territory will be completed in the coming year.

(*d*) *Queensland.*—The resources of the regional team have been concentrated for the past three years on a comprehensive survey of potential irrigation lands in the valley of the lower Burdekin River. Infiltration studies have been made in addition to a soil survey of a reconnaissance type over the whole area and a detailed survey of several sections. Field work is now complete, and compilation of the final reports and maps is in progress. The aim has been the study of the nature of the soils in relation to irrigation water on possible crops or pastures. Considerable experimental work in this regard can now be built on these foundations.

A start is being made on detailed surveys of two areas on the Darling Downs, one of a section of hilly downs in the neighbourhood of Toowoomba, and the other of open downs nearer to Dalby. These will form part of a study of the black earths of the region and assist with an understanding of the current research in fertility problems on the soils.

(*e*) *Tasmania.*—The Tasmanian regional group has extended its work on the northern river system of the island in the Launceston Tertiary basin. Much detailed information has been gathered on the soil resources of this area, and field work is nearing completion. It has been deferred for the more urgent requirements of a survey on Flinders Island.

A preliminary reconnaissance covering about 100 square miles has been carried out on Flinders Island, at the request of Commonwealth and State land settlement authorities. Problems in drainage, salinity, and soil deficiencies have been defined and indicate the essential need for soil and agronomic studies. It is proposed eventually to cover the whole island, an area of about 600 square miles, with a view to intensification of settlement. Aerial photographs recently received from the Tasmanian Department of Lands will enable the work to be put on a satisfactory mapping basis and to continue with the greatest possible facility when the survey is resumed.

(*f*) *Western Australia.*—The major reconnaissance of the south-east Stirling area, embracing some 800 square miles of forested and scrub-covered country in the neighbourhood of Albany, has been completed. Special attention has been given to the problem of salinity, which is prevalent in the soils of this and adjacent areas, some already surveyed, in the lower south-west.

Selected portions of the coastal lands to the south of Perth, which were mapped in terms of soil associations during the previous year, have been examined in more detail. The region, which extends from the coast

to the western scarp of the Darling ranges, presents a variety of soil conditions and includes several small irrigation areas which may be further developed. A detailed survey of the Government Experimental Farm at Wokalup in the southern sector of the region has been made and a transect of the coastal belt amounting to 20,000 acres largely completed.

Special closely detailed spot surveys have been carried out at Bindoon, on the Midland Plain, for potential horticultural development, and at the Plant Introduction Station at Kelmscott, near Perth.

The survey programme in Western Australia has taken full cognizance of the needs of War Service Land Resettlement authorities, both Commonwealth and State. Shortage of trained staff has limited the amount of assistance which could be given, but nevertheless it is expected that during the coming year, as a continuation of previous policy, considerable progress will be made by the regional unit towards furthering development schemes.

(*g*) *North Australia.*—Responsibility for the North Australia survey, which has been undertaken since 1946 in conjunction with the Division of Plant Industry, is now vested in a new unit, the Land Research and Regional Survey Section. An officer of the Division of Soils has been seconded to this unit, which is engaged on surveys of the large under-developed areas in North Australia, Papua, and New Guinea. This work is reported in Chapter III., Section 21.

3. Soil Chemistry Section.

(*a*) *Basaltic Soils from Lismore, New South Wales.*—The chemical work on the basaltic soils from Lismore, New South Wales, has been completed during the year and is now being prepared for publication as part of a bulletin on this area. A fractionation of sodium, potassium, calcium, magnesium, and strontium present in these soils has been carried out, and the graphical presentation of these results indicates some of the chemical differences between the various soil types recognized in the field survey.

(*b*) *Availability of Copper and Manganese.*—Studies on the availability to plants of copper and manganese have been continued. During the year a pot experiment carried out with oats showed that considerable differences in uptake by plants can result from different methods of application of these nutrients to soils. On a naturally deficient soil from Robe, South Australia, greater uptake of added copper resulted from an application mixed throughout the soil than from the same amount applied in solution to the surface. Uptake of added manganese also differed with these two methods of application in the soils investigated. Usually, but not invariably, higher uptake resulted from applications made in solution to the soil surface. Both copper and manganese applied in this way remained very largely in the top half-inch of soil at the conclusion of the experiment. It is considered that in any investigation of the chemical aspects of availability of these metals, care should be given to ensuring that treatments are distributed as uniformly as possible through the soil. This work is being continued by means of further pot experiments.

(*c*) *Ion Exchange and pH Relationships of Cation-dominant Soils.*—A start has been made upon an investigation into the ion exchange and pH relationships of various cation-dominant soils chosen with special regard to the nature of the predominant clay mineral present. Bulk samples of each of the soils are being made dominant in each of the cations, calcium, magnesium, potassium, sodium, and hydrogen, by exchange with the appropriate salt solution and leaching with aqueous alcohol. When these treatments are complete, information of a fundamental nature will be provided about the variation of reaction with type of clay mineral and relative cation status. This will be obtained by examination of the prepared soils and of mixtures compounded from them. Such information should aid in the interpretation of soil reaction in the light of other analytical data. The preliminary examination of the analytical methods to be used for this experiment has been completed and work is now beginning on those soils already prepared. The electrode system for the determination of soil pH is being further investigated in order to assess the extent to which variation in reaction with dilution depends upon the junction potential between the potassium chloride bridge and the soil particles. Early results show that for soils the error due to this cause is small.

(*d*) *Terra Rossa and Rendzina Soils.*—A chemical study of the inter-relationships of terra rossa and rendzina soils in South Australia has been begun. Many representative profiles have been examined and samples collected. These morphologically different soils occur in close proximity and on similar parent material. Geographically, their main areas of development are in the vicinity of Adelaide and in the south-east of the State.

(*e*) *Spectrochemical Investigations.*—Spectrochemical investigations have been continued and soil profiles representative of the more important soil groups of South Australia have been examined. The quantitative distribution of several of the less common metallic constituents of these soils is being determined throughout the different soil horizons. Further attention has been devoted to the difficulties associated with the accurate quantitative determination of the elements in soils and plant ash of such variable base composition as is commonly encountered. The effects of the presence of excess potassium sulphate and excess calcium sulphate in a plant ash on the emission of radiation by copper, manganese, molybdenum, and tin have been investigated. Potassium sulphate was found satisfactory as a spectographic buffer for samples of plant ash. Difficulties encountered in the accurate determination of manganese in plant ash were found to be due to pronounced self-absorption of the analysis line. An equation has now been developed which fits the experimental results satisfactorily over a tenfold range of concentrations of manganese. The application of statistical methods to spectrochemical investigations such as this has proved fruitful not only in reducing the amount of work but also in increasing the reliability of the results.

The facilities of the Division have been made available for training an officer of the Division of Plant Industry in spectrochemical techniques and the officer has assisted with the investigations in progress.

(*f*) *Special Analytical Methods.*—Regional laboratories have been operating throughout the year in Brisbane, Perth, and Hobart, and these laboratories have materially assisted in reducing the number of soil samples examined at the head-quarters of the Division. This has made it possible to conduct more detailed analytical work on selected samples from the soil surveys. Chemical analyses have been carried out on the clay fractions of different soils, and the results studied in conjunction with X-ray diffraction patterns and exchange capacity determinations. In many soils, particularly some containing abnormally large amounts of soluble salts or calcium carbonate, direct determinations of exchange capacity have been made by measuring the ammonia absorption. The air-acetylene flame spectrograph has been used for the determination of cations in a number of water samples in connexion with soil-salt studies.

A satisfactory method has been developed for the determination of free iron oxide in soils. Because reduction is brought about by nascent hydrogen at room temperature and under conditions of mild acidity, attack on other soil constituents is at a minimum. The method has been widely used in studying the amounts of free iron oxide in the red loams from Lismore, New South Wales. Work on the possibility of the simultaneous determination of calcium, magnesium, potassium, and sodium by direct measurement of the air-acetylene flame emission lines by photo-multiplier tubes has been continued with the assistance of the Physics Department of the University of Adelaide. The method has been found feasible but the practical difficulties are great. During the year a portable conductivity unit was built to permit the measurement of soluble salts by soil surveyors in the field. An improved mixed indicator was also developed for rapid colorimetric determination of soil reaction in the field.

4. Soil Physics and Mechanics Section.

(*a*) *Soil Structure.*—The stability of the natural structural aggregates of soil is of importance both to agriculture and to engineering. The irregular shape and wide size range of the structural aggregates in soil make it difficult to measure their friability. Artificially moulded specimens of regular shape have received some attention but little work has been done on the stability of naturally occurring aggregates. In work which has now been published, it has been shown that natural aggregation can be measured by means of a drop-shatter method. The dropping procedure subdivides aggregates along surfaces of weakness into smaller natural units. The method has been used to help define the structure and consistency of soils of the Riverina and Abermusden districts, New South Wales. Soils under various crop rotations were examined at the Waite Institute by this procedure. It was found that plots which included one year of pasture in the rotation had larger aggregates after shattering than those from which pasture was omitted.

The tendency for aggregates to break down in water is the basis for another method which has been under examination. It was shown that in a suspension procedure for determining aggregation a short period of shaking showed to advantage over longer periods when the effects of different cultural treatments were to be distinguished. Conclusions were also reached on other features of the technique, including the methods of wetting and shaking. The disaggregating effect of air entrapped during wetting of soil is an important factor, and it has been shown that breakdown increases with decreasing water content of the soil at the time of wetting.

(*b*) *Soil Colloids.*—A study is being made of the clay fraction of the red-brown earth group of soils.

The examination of profiles from South Australia, Victoria, and New South Wales shows the clay fractions to be mixtures of illite and kaolinite, with illite predominant. The proportions of these clay minerals appear to remain constant throughout each profile, though they vary from one profile to the next. Red-brown earths from the Adelaide area contain small amounts of montmorillonite and chlorite in addition to illite and kaolinite.

The X-ray studies on the clay fraction of several Queensland soils reported as red-brown earths show them to be mainly kaolinite, so that they appear to be somewhat different from the other profiles studied.

Work is continuing on the fluorescent X-ray spectrograph. A curved-crystal focusing spectrograph has been built and appears satisfactory for the rapid determination of certain elements in the clay fraction. Further work on it is proceeding.

(*c*) *Movement of Water in Soils.*—Infiltration measurements have been carried out in the Burdekin Valley, Queensland, and in the Barossa Valley, South Australia. The object has been to determine the characteristics of soils mapped in the course of the Division's soil surveys. The results in the Burdekin Valley are of significance in relation to the question of future irrigation developments.

The methods used in these measurements have been reviewed in a paper on the effect of lateral movement of water upon the results obtained from small infiltration plots. Results were greatly influenced by the size of plot used. It was shown that the minimum infiltration capacity of a given soil varied inversely with the fraction of applied water remaining directly under the plot at the conclusion of the trial. When this fraction was used as a correction factor, results from small plots were similar to those from larger ones and there was in addition a reduction in the variability of the results obtained from small plots.

The tendency for water to move under the influence of a temperature gradient is being examined. In a closed system, considerable movement will occur from the hotter towards the colder end. The present work is throwing light on the mechanisms involved. Water moves as vapour towards the colder end and, in a closed system, there is a return flow as liquid in the opposite direction. Under these circumstances, vapour equilibrium cannot be reached. Measurement of the redistribution of the small amount of soluble salt occurring naturally in the soil has indicated the direction of liquid flow.

(*d*) *Changes in Water Content and Movement of Soils under Covered Areas.*—Records are being kept of changes occurring under a number of areas covered by small buildings and pavements in Melbourne and Adelaide. It is of importance in the design of dwellings and of pavements for the behaviour of expansive soils to be known. Information on long-term and seasonal changes in the water content and in the vertical movement of soils is therefore being obtained. Annual movements of up to three inches have been noted near the surface of certain exposed clay soils at Adelaide. During the past year additional installations of devices for measuring moisture and temperature have been made at Essendon airport in co-operation with the Commonwealth Department of Works and Housing. In all work with a bearing on engineering problems, close co-operation has been maintained with that Department, with the Commonwealth Experimental Building Station, and with State highway authorities.

The changing moisture status of soils under covered areas has been followed by determining changes in the electrical conductivity of gypsum blocks embedded in the soil. Techniques relating to the use of these blocks have been examined in a paper which discusses their usefulness for the indirect measurement of tension in soil water.

The shrinking and swelling process responsible for soil movement is being studied in the laboratory. The relationships between volume, water content, and tension changes in clay soils are being ascertained.

(*e*) *Examination of Soils for Engineering Purposes.*—Mapping of soils of building areas for the housing authorities of Melbourne and Adelaide has continued, the largest areas handled recently being those at Preston, Victoria, and South Para, South Australia. A generalized soil map of Adelaide is being prepared and the characteristics of the soils are being determined with the assistance of a mobile laboratory. Information on the distribution of soils, their physical properties, and the geological features of Adelaide suburban areas is being prepared for publication in co-operation with the South Australian Department of Mines.

Similar work is to be done in the suburbs of Melbourne, for which an interim soil map has already been prepared.

5. Soil Microbiology Section.

Preliminary studies have been commenced on the relationships of soil micro-organisms to subterranean clover (*Trifolium subterraneum*) involving field trials at Parndana, Kangaroo Island, Lucindale, Keith, and Urrbrae, and greenhouse trials at the Waite Institute. These studies have been developed along two lines. On the one hand it has been found that as well as stimulation in the rhizosphere, a wide range of fungi are able to invade the root tissues and set up a chronic infection. This does not necessarily affect adversely the growth of the host plant unless some form of environmental or nutritional stress is encountered. The commonest environmental stress to which clover plants in a sown pasture may be subject is that due to lack of moisture during a dry spell, but severe frosts or waterlogging under heavy rainfall conditions are also indicated as factors. The commonest nutritional stress encountered in southern Australian soils is a limited supply of phosphorus, particularly in lateritic soils with high phosphate-fixing powers, but less commonly nitrogen may become the limiting element. Under such conditions the chronic infection may develop into systemic parasitism, and plant growth rate is diminished to such a degree that yield is significantly reduced. In cases of most severe attack the plant may fail entirely before setting any seed, as usually happens when it is affected in the early stages after emergence. Less severe attack may be manifested in extensive root-rot. In establishing sown pasture on new land, inadequate supply or inefficient placement of superphosphate is accompanied by large numbers of poor plants which usually succumb to infection.

Investigations conducted concurrently have shown that symbiotic nitrogen-fixing bacteria of the genus *Rhizobium* capable of forming an effective association with subterranean clover appear to be indigenous in many southern Australian soils, although numerically suboptimal to contribute completely the full season's requirement of nitrogen by the plant. Such indigenous rhizobia isolated from a number of field sites in South Australia have been found to be mostly effective and partially effective types in their powers of nitrogen-fixation, although ineffective types are also found. Autumn-sown subterranean clover in these soils tends to be inadequately nodulated in the early stages where inoculated seed is not used, but over the winter period stimulation in the rhizosphere results in an extension of nodulation. By the end of the growing season nitrogen supply is not limiting to the plant, and no significant differences in herbage yield occur between control plots and plots sown with seed inoculated with various strains of *Rh. trifolii*. This is also due in part to difficulties in establishing the inoculated strain into the soil microflora, and investigations are being continued to ascertain the basis of such resistance.

Greenhouse trials using pot cultures have been conducted on the effects of competition between different strains of *Rh. trifolii* for nodulation of subterranean clover. These have shown that some highly effective strains of rhizobia may fail, if used as commercial inoculants, owing to their inability to withstand competition from less effective or ineffective strains indigenous in the soil. In selecting strains of rhizobia for commercial purposes, equal emphasis must be placed upon this character and upon effective nitrogen fixation.

The range of rhizobia isolated from naturalized alien and indigenous members of the Leguminosae comprising elements of the native vegetation has been extended by isolations from additional species in genera studied previously as well as in the additional genera *Daviesia, Viminaria, Gompholobium, Eutaxia,* and *Swainsona.* Cross-inoculation studies of these rhizobia indicate that their natural affinities seem to lie with the so-called cow-pea cross-inoculation group, although some strains do not form nodules on *Vigna unguiculata* or *Acacia pycnantha* and thus may belong to strain-specific suites within this group. Uniform lack of nodulation of soybean, French bean, clover, lucerne, field pea, or lupin indicates any absence of direct relationship to the cross-inoculation groups characterized by these hosts. Thus the likelihood that the indigenous clover rhizobia have formed a symbiotic association with leguminous hosts of a previous native vegetation is not great.

Serological techniques developed in England and successfully used there in the study of efficiency of inoculation of red clover with selected strains of rhizobia in competition with native strains have been applied to a study of the antigenic relationships of isolates from subterranean clover in South Australia and New South Wales. This work has been completed and is being prepared for publication. A wide range of antigenic types of diverse distribution has been found, with little definite district relationship.

III. PLANTS.

1. General.

Investigations of plant problems related to Australia's primary industries constitute an important part of the activities of the Organization. This work is undertaken mainly by the Division of Plant Industry and is described in Sections 2-16 and 18 of this Chapter. Plant problems in Northern Australia are being investigated by the recently formed Land Research and Regional Survey Section. This work is described in Sections 17 and 19-21 of this Chapter.

Studies on the mineral nutrition of plants in the Ninety-mile Plain, South Australia, carried out by the Division of Biochemistry and General Nutrition, are described in Section 22.

Work on the special problems of irrigation districts, undertaken by the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales, is reported in Chapter IV.

The Division of Entomology is carrying out work on insect pests of pastures and crops, biological control of weeds, and insect vectors of virus diseases. This is described in Chapter IX.

Division of Plant Industry.—The head-quarters and main laboratories of the Division are at Canberra, with field stations and laboratories at the following centres throughout the Commonwealth: Australian Capital Territory: Dickson Experiment Station; New South Wales: Regional Pastoral Laboratory and Falkiner Memorial Field Station, Deniliquin; Mitchell Laboratory, Trangie; Queensland: Plant and Soils Laboratory, Brisbane; Cooper Laboratory, Lawes; Plant Introduction Station, Redland Bay; Horticulture Station, Stanthorpe; Tobacco Station, Ayr; Western Australia: Plant and Soils Laboratory, Perth; Glen Lossie Field Station, Kojonup; Plant Introduction Station, Kelmscott; Tasmania: Regional Laboratory, Stowell. In addition, officers of the Division are stationed at Sydney, Armidale, and Griffith, New South Wales, Cunnamulla, Queensland, Katherine, Northern Territory, and the Waite Institute, Adelaide.

The investigations of the Division are planned to increase the carrying capacity of pastures for wool, meat, and dairying products; to reduce losses from crop diseases and weeds; to further the development of new production, particularly under summer rainfall conditions; and to study special crops such as potatoes, tobacco, and drug plants. Unfortunately the lack of sufficient laboratory space at Canberra is still an acute problem and a handicap to the work.

At the request of the Australian Agricultural Council the Division organized two conferences of State and Commonwealth Officers. A conference of Potato and Vegetable Research Workers was held in Canberra and Sydney in October, 1950, and in December, 1950, a conference of Tobacco Technical Officers met at Ayr. Both conferences were invaluable as they enabled State and Commonwealth Officers engaged in both research and production problems to exchange information and experiences to the ultimate benefit of production in Australia.

2. Plant Introduction.

The Plant Introduction Section is responsible for the introduction of plants and seeds from countries similar climatically to Australia, and for their testing here. The introductions are obtained through correspondence and overseas plant exploration, and are selected with special reference to their probable value in Australia. In testing introduced plants, the Section maintains close relations with specialists of the Division, with the State Departments of Agriculture, and with the Department of Health, which is responsible for plant quarantine.

(*a*) *Introduction and Exchange of Plants and Seeds.*—During the year 518 samples of seed and plant material were introduced from 33 countries for trial in Australia. As in previous years, pasture and forage plants comprised the principal introductions, more than half the total number being in these groups. Of the remainder, plants for trial in the tropical and subtropical parts of Australia were of greatest importance. These included many varieties of fibre plants, such as cotton and hibiscus, and of rice and leguminous pulses. As many of these plants have not hitherto been grown extensively in northern Australia, particular attention has been given to strict quarantine measures to prevent the introduction of diseases and pests which might impede their development here.

Most of the introductions were from the United States of America and India, with many also from Canada and Portugal. Excellent relationships have been established with the United States, Portugal, and Canada over many years, while contacts with India have been stimulated by visits of agricultural scientists to and from that country.

Some 956 samples have been sent to overseas countries in exchange, the principal recipients being India, United States of America, Argentina, Greece, France, and Spain. A new and enlarged seed exchange list has been prepared and will greatly facilitate overseas contacts.

In addition to the trials of introduction under the direct control of C.S.I.R.O. officers, upwards of 660 samples have been distributed for trial by State Departments of Agriculture and similar organizations within Australia. They include many plants of value for erosion control, in which there is evidence of renewed interest in several States. Close contact has also been maintained with the Department of Agriculture, Stock and Fisheries of Papua and New Guinea, and plant material has been introduced for and supplied to that Territory.

(*b*) *Plant Exploration.*—In the latter part of the year it was found possible to develop active collection of plant material in other countries with a view to its testing in Australia. Such plant exploration forms an essential part of plant introduction work, as it permits a careful selection of plants in relation to Australia's requirements and makes available much material not readily obtainable through correspondence.

Arrangements were made for a Merchants Research Fellow, from Western Australia, who had attended the Pan-Indian Ocean Science Congress at Bangalore in southern India, to visit agricultural research stations and similar institutions in that country. As a result of these visits much interesting material is being received which should be valuable in the Northern Territory and the Kimberley district of Western Australia.

At the end of the year two officers of the Division were in the Mediterranean region collecting pasture and other plants, including especially varieties of subterranean and other clovers, medics, and grasses. Countries visited include Turkey, Israel, Syria, Cyprus, Greece, Italy, France, Spain, Portugal, North Africa, and Egypt. It is anticipated that the material collected will for the first time permit an adequate assessment of the potentialities of a region which has already contributed numerous plants of great value to Australia.

During the coming year further collecting will be undertaken in tropical and South Africa, the primary objectives being new pasture and forage plants for Queensland and northern Australia.

(*c*) *Pasture and Forage Plant Trials.*—(i) *South-eastern Australia.*—A total of 591 species and strains of pasture and forage plants were under trial in rows at Canberra during the year. Most of them were perennial grasses and annual or perennial legumes, but annual grasses and miscellaneous forage plants of other families were also included. Among the latter some species of *Sanguisorba* and *Poterium* were of particular interest, showing good drought resistance and an ability to grow actively in late summer and autumn. The possible value of these pasture plants is being further tested at Armidale.

A trial sown during the previous year to test the usefulness of some of the more productive introduced grasses in association with phalaris and subterranean clover was handicapped by excessively wet weather during the earlier months, but fair establishment was obtained and the plots will be grazed at regular intervals during the coming year. It is anticipated that the trial will indicate whether introduced grasses may be used to supplement the standard species during periods when the latter are relatively unproductive.

Work at regional trial centres conducted in association with the nursery trials at Canberra has been further extended during the year, and an important development has been the establishment of pasture plant studies at Crooble, near Moree. These trials not only assist in assessing the value of introductions to meet special local requirements, but also facilitate the overall evaluation of promising new varieties. Some of the results in northern New South Wales are of special interest, and several species of *Phalaris, Panicum, Stipa, Sorghum,* and *Dactylis* are proving of value in a region in which plant introduction has hitherto received little attention.

Lathyrus ochrus, which had previously shown great promise as a green manure species at Mildura, was grown at several properties in the region during the period under review. These further trials confirmed the value of the plant for use in vineyards, especially on the lighter soils, where it proved superior to tick beans. These trials were conducted under the supervision of officers of the Commonwealth Research Station, Merbein.

(ii) *Queensland.*—Further evaluation of pasture and forage plant introductions, especially those collected in South America, has formed the main activity of the plant introduction station at Redland Bay, near Brisbane, during the year. A technique has been evolved, based on defoliation cuts at regular intervals combined with toxicity tests and chemical

analyses, which has enabled a rapid assessment to be made of the potential value of a large number of varieties. From the range of pasture introductions studied, 20 have been selected as meriting special attention. These include eleven varieties of *Paspalum*, three of *Desmodium* and *Stylosanthes*, and one each of *Phalaris*, *Phaseolus*, and *Arachis*. The climatic and edaphic adaptabilities of these varieties are being further tested at Gladstone, Urimbah, Lawes, Maryborough, Kuraby, and Cecil Plains, Queensland, in co-operation with the Agrostology Section, and at Lismore, New South Wales, in co-operation with the University of Sydney.

Some of the perennial peanut introductions are promising as pasture plants, but their usefulness is limited by poor seed production. In commercial peanuts it has been shown that low seed production is often associated with calcium deficiency, and an experiment has therefore been begun to test the effect of different nutrient treatments on the wild species.

(iii) *Northern Territory.*—At the Katherine Experiment Station, about twelve grass introductions which had shown promise in preliminary nursery row trials are being further studied. Information is being obtained on the cycle of growth and nitrogen content, on the time of breaking of dormancy after the dry season, and on the leaf-stem ratio. It is anticipated that this work will shortly be completed, and will enable the material to be patterned out into groups of varying climatic and edaphic adaptability. The most promising introductions at present include strains of *Cenchrus ciliaris*, *Panicum coloratum*, *Panicum maximum*, and *Digitaria* spp.

Of the pasture legumes under trial, the most valuable include Stylo, *Stylosanthes bojeri* (from Tanganyika), and *Terannus labialis* (from British Guiana). Some supplementary irrigation is required to extend the growing season for Stylo and thereby permit its full development.

Further trials have confirmed the value of species of *Phaseolus* as grain legumes, and indicate that yields of 1,000 lb./acre of grain containing 23 to 25 per cent. of protein should be obtainable on a commercial scale. No responses have been shown to different fertilizer treatment or seeding rates.

(iv) *Western Australia.*—During the year a new plant introduction station was established at Kelmscott, near Perth, which will be developed as the principal nursery quarantine centre for the State. The establishment of this station will allow more attention to be given to pasture plants, including both annuals and perennials, and it will be particularly useful as a centre for testing new introductions resulting from intensive collecting in the Mediterranean region.

Replicated trials were conducted at Perth, Kojonup, and Wokalup to obtain further information about the agronomic value of vetches and other grain legumes and their possible usefulness in combination with oats. In general, these confirmed the results of previous trials, but in mixtures with oat varieties the one-flowered vetch (*Vicia articulata*) was largely suppressed, possibly because of the exceptionally favorable seasonal conditions for oat growth.

Close liaison has been maintained with the Western Australian Department of Agriculture, and extensive field trials of promising introductions were conducted by the Department. Highly favorable reports have been received on the performance of some of the vetch varieties released by C.S.I.R.O., while a perennial brome grass, originally received from Lithuania as *Bromus popovii*, has been outstanding in the south-western dairy belt.

(*d*) *Trials of Crop Plants.*—Studies of vegetable oil plants have been continued, especially at Lawes, Queensland, and Katherine, Northern Territory. The season at Lawes was unusually wet, favouring the development of rust in the linseed varieties, and some rust-susceptible strains from India which had given good results in previous years had low yields. However, some other introductions continued to compare very favorably with the standard variety (Walsh) used as control.

Introduced sunflower varieties from Canada, Argentina, Uruguay, and several European countries are under trial at Lawes, and studies of flowering and seed-setting have been continued. These studies have as their object improvements of the basic techniques required for the development of hybrid varieties in Australia similar to those which have proved of outstanding value in Canada.

The main objective of the safflower work at Lawes has been to obtain high-yielding spineless types, and some progress has been achieved. Under favorable conditions in small scale trials, almost spineless selections have yielded at the rate of over 1,000 lb./acre. Several recent introductions are showing promise.

Only a restricted programme of work with vegetable oil crops has been conducted at Katherine, and there are no outstanding results to report. It has been shown that several oil crops, including peanut, rapeseed, sunflower, and sesame, are well adapted to the climatic and other conditions, and produce yields fully comparable with those in other countries, but a choice between them must depend upon further investigations of the requirements for balanced agricultural development in the Territory. Analyses made in England indicate that sunflower oil produced in northern Australia is of particularly high value for the food industries.

Peanut variety trials, involving many varieties from South America and South Africa, have been completed at Redland Bay. A rigid quarantine check has been made, and the most desirable agronomic types have been selected and released for further trial in the Northern Territory and by the Queensland Department of Agriculture.

Cereal variety trials have been continued in Western Australia, while technical plants under investigation include canaigre (*Rumex hymenosepalus*), a possible commercial source of tannins, and kenaf (*Hibiscus cannabinus*), which yields a fibre which can be used to replace jute.

(*e*) *Other Investigations.*—As part of a general programme designed to strengthen the theoretical and practical basis of plant introduction work, studies have been undertaken on some aspects of plant geography. A paper has been published dealing with the relationship between grass distribution throughout the world and climatic factors, and this will form the basis of a floristic method of comparing plant envirounent in widely-separated regions.

The Plant Introduction Section is also preparing a map of Australian vegetation which will form part of an Australian Resources Atlas sponsored by the Department of National Development. Apart from its more obvious uses, this map should be of value in comparing Australian vegetation with that of other parts of the world from which our plant introductions are obtained.

At both Canberra and Brisbane, studies are being made of the growth and development of selected grasses in relation to seasonal conditions here and the climate of the countries of origin. It is hoped that these studies will lead to the development of a technique enabling plants found promising in initial nursery trials to be allocated with more confidence for further trial in the most suitable areas.

A project of more immediate practical importance is the preparation of an inventory of economic plants under cultivation at experiment stations, botanic gardens, and similar institutions in Australia. An excellent response has been received to a questionnaire which was sent out to all appropriate organizations and the composite inventory is in preparation. It will be of value in reducing unnecessary duplication in the testing of plants at several centres, in dealing with overseas requests for seeds and plant material, and in helping to ensure that all worth-while plants receive adequate trial.

(*f*) *Herbarium.*—The number of specimens now incorporated in the herbarium is 23,168, an increase of 2,133 sheets during the year. Routine determinations have continued in connexion with the work of officers of the Division, of the Land Research and Regional Survey Section, and of other governmental and private bodies. The collections have also been enriched by specimens received in exchange from other countries, including South Africa, Uruguay, and Holland. Collections of seed of native plants were made for use in plant introduction exchanges.

Owing to the reduced number of routine inquiries it was possible to give greater attention to original research, and during the year a revision of the Australian species of *Triodia* was completed and presented for publication. Some time has also been given to a study of distribution problems in the Australian flora, particularly *Acacia* and *Eucalyptus*, and a paper entitled "Some effects of the arid period on distribution pattern in the Australian flora" was presented at the Brisbane meeting of the Australian and New Zealand Association for the Advancement of Science.

At present a considerable amount of time is being given to the plant material collected in the Northern Territory by botanists of the Land Research and Regional Survey Section. It is hoped to accumulate information on the distribution of plants in northern Australia and to combine it with information on their ecology.

3. Plant Genetics.

A Section of Plant Genetics has again been established within the Division, embracing the genetical work and staff described previously under the heading of Vegetable Investigations. The scope of the work has been increased to include genetical and cytogenetical investigations of important and potential pasture species for Australian conditions, certain cereal problems not being pursued elsewhere, and problems in the disease resistance of major vegetable crops such as the tomato and the potato. It is anticipated that genetical problems of crops and species important in the north of Australia will be tackled in the future as staff and facilities become available.

(*a*) *Induced Autopolyploidy in the Important Pasture Species of Australia.*—Aqueous 0.4 per cent. colchicine solutions were used to double the chromosome number of subterranean clover (*Trifolium subterraneum*), white clover (*T. repens*), lucerne (*Medicago sativa*), various annual *Medicago* species, and grasses like *Paspalum scrobiculatum, Phalaris tuberosa, Chloris gayana,* perennial ryegrass (*Lolium perenne*), and Wimmera ryegrass (*Lolium* spp.). Autopolyploids were easily produced in the leguminous species, whereas special techniques had to be developed for their induction in grasses. Anatomical, physiological, and agronomic aspects of the autopolyploids are being investigated in order to assess their adaptability to field conditions. Low fertility will restrict the use of most of them. In addition, it is obvious that polyploidy has a beneficial effect in only a few of the species, the majority, like subterranean clover, being reduced in vigour.

(*b*) *Induction of Gene Mutations in the Important Pasture Species of Australia.*—It is considered that the production of mutants or mutant characters could be a factor in increasing the range of adaptability of some of our major pasture species. Various chemical mutagens have been tried, but up to the present none has been found particularly effective.

X-ray dosages of 10,000 to 20,000 rontgens have been applied to dry seeds with a view to inducing mutations in the resultant plants. In general, graminaceous species like *Phalaris tuberosa* and *Lolium perenne* will not tolerate high dosages but leguminous species like *Trifolium subterraneum* and *Medicago sativa* are not injured by 20,000 rontgens. Subsequent generations from the R1 plants will reveal mutant types which have been produced.

(*c*) *Examination of Interspecific Relationships of Certain Genera Containing Important Pasture Species.*—The main genera being examined at present with a view to the production of interspecific crosses and the subsequent production of allopolyploids are *Medicago* (annual types), *Phalaris,* and *Ehrharta.* It is hoped to extend this investigation to other genera potentially important in Australia. These investigations could result not only in extending the range and adaptability of some of our major pasture types but also in the synthesis of new and vigorous pasture species.

(*d*) *Genetics of Resistance to the Mosaic Viruses of the Potato.*—This investigation, which has been proceeding for some ten years, has resulted in the successful production of high-yielding potato seedlings of good agronomic quality which resist the major mosaic virus diseases in the field. The agronomic aspects of this work are being done in conjunction with State Departments of Agriculture. A study of the phenotypic reactions among the seedlings of hybrid progenies has resulted in an understanding of the possible genotypes involved.

(*e*) *Development of Resistance to the Leaf-roll Virus in the Potato.*—This is now the most important problem in the potato. Work here has shown a wide range in reaction to leaf roll among the phenotypes from different hybrid progenies. Phloem necrosis has been used as an index of severity of reaction. Glasshouse and field experiments in progress with a number of hybrids reacting with different degrees of phloem necrosis may give a lead to the phenotypic reactions resulting in resistance.

(*f*) *Spotted Wilt Resistance in the Potato.*—Field experiments had shown that varieties like Katahdin possessed a high degree of resistance to spotted wilt while varieties like Factor were very susceptible. It was found that the usual method of hand inoculation of the leaves in glasshouse experiments had to be modified if a true indication of the phenotypic reactions amongst seedling progenies and varieties were to be obtained. The modification which proved successful was the inoculation of young growing tips at the flowering stage with an ordinary mixed culture of the spotted-wilt virus.

(*g*) *Genetics of Spotted Wilt Resistance in the Tomato.*—Work here and elsewhere with hybrid tomato progenies developed for spotted wilt resistance has given no indication of the genotype involved and has not resulted in the development of commercial types with the required resistance. It became obvious that a study of the phenotypic reactions to spotted wilt of *Lycopersicon* species, with various degrees of resistance, was a necessary basis for genetic work on this problem. Experiments have shown that a virus inactivating mechanism sensitive to temperature is present in *L. pimpinellifolium, L. peruvianum,* and *L. esculentum* var. Rey de los Tempranos. Hybrid progenies can now be assessed for spotted wilt resistance with some degree

of accuracy. The high resistance of *L. peruvianum* is being incorporated into *L. esculentum* types by the production of triploids.

(*h*) *Genotypes for Eelworm Resistance in the Tomato.*—This work is being done in conjunction with the Commonwealth Research Station, Merbein. The high resistance of a tomato accession originating from a *L. esculentum-L. peruvianum* hybrid developed by embryo culture at Davis, California, has been confirmed under Murray Valley conditions. Suitable hybrid progenies are being developed and tested in eelworm-infested soil with a view to finding the number of genes involved and developing agronomic types for the Murray Valley. Agronomic selection and testing are being done by the South Australian Department of Agriculture.

(*i*) *Genetics of Resistance to Legume Viruses in* Pisum sativum *and* Trifolium subterraneum.—Subterranean clover and garden peas are sometimes attacked by certain legume viruses. Two legume viruses similar to Bean Mosaic II. have been isolated and are being used to distinguish resistant phenotypes in pea progenies involving varieties like Greenfeast, William Massey, and Canners' Perfection. The segregations so far have indicated that only one major gene may be necessary for resistance in peas. With subterranean clover, a relatively large number of varieties are being tested to isolate types resistant to one or both of the legume viruses being used.

(*j*) *Cytological Investigations.*—It is intended that a cytological study of all material involving polyploidy and interspecific crosses be made. Chromosome counts in root tips of the material involving *Lycopersicon* species have been commenced.

4. Plant Diseases.

The work under this heading is carried out in the Section of Microbiology and deals with plant pathology, virus studies, pure culture collections, and antibiotics. Special attention has been given to virus diseases with the object of control by chemotherapy. Investigations on the use of antibiotic substances for controlling plant diseases are continuing. The Division is assembling and maintaining a Commonwealth collection of fungal and bacterial plant pathogens in Canberra.

(*a*) *Potato Virus Diseases.*—(i) *Potato Virus X.*—An experiment designed to determine the relative rates at which virus X will spread in five potato varieties gave anomalous results suggesting either incomplete invasion of the tubers of a plant or a mode of spread other than by plant-to-plant contact. Further observations are being made.

(ii) *Purple Top Wilt.*—Observation in storage of tubers derived from plants infected with this disease, caused by the Tomato Big Bud virus, showed that it caused the "hair sprout" or "thready eye" condition in a high percentage of tubers, although some were apparently free of virus. A large number of affected tubers was grown in the glasshouse and the virus recovered by grafting to *Datura stramonium* from the resultant dwarfed plants.

(*b*) *Plant Tissue Culture Techniques in Virus Studies.*—(i) *Root Growth.*—Difficulties encountered in the growth of tomato roots in synthetic media have been investigated and a satisfactory technique evolved using White's medium. Clones of tomato roots with and without virus X have been set up and studies commenced with the addition of chemotherapeutic agents to the culture medium to inhibit the multiplication of virus X. Attempts to grow potato roots have been unsuccessful.

(ii) *Culture of Apical Meristem of Potato.*—The apical meristem of numerous potato shoots has been dissected out aseptically and placed on synthetic nutrient medium. Successful growth was obtained in several cases. Sterile clones of plantlets are now available for further studies. Best growth occurred when coconut milk was added to the medium.

(iii) *Potato Callus Tissue.*—Undifferentiated callus tissue infected with virus X was derived from potato stems by planting segments aseptically on nutrient agar. Pieces of callus transferred from these stems to other nutrient agar in which 2,4-D was used as a growth hormone have continued to multiply and will be used in chemotherapy studies.

(*c*) *Witches' Broom Disease of Lucerne.*—Field studies of Witches' Broom disease, begun in 1947 and designed to give information on the effect of the disease on individual plants as well as on a stand of lucerne as a whole, have been concluded.

A glasshouse controlled watering experiment has shown that symptom expression of diseased plants is influenced by water supply and by frequency of cutting. The combination of high water supply and frequent cutting causes a high mortality rate of diseased plants.

Transmission of the disease to a number of new hosts has been obtained by using *Cuscuta campestris* as an intermediary host, and also by grafting. The host range includes tomato, potato, carrot, lettuce, petunia, *Calendula, Datura stramonium, Datura tatula, Vinca rosea, Vinca alba, Nicotiana glutinosa, Nicotiana rustica, Nicotiana tabacum, Nicotiana tabacum* var. *atropurpureum,* and *Crotalaria goreensis.* The symptoms of Witches' Broom disease on these hosts strongly resemble those of Big Bud of tomato, and it seems likely that these two diseases are caused by the same virus.

(*d*) *Potato Diseases.*—(i) *Common Scab.*—A further field trial of varietal resistance to Common Scab (*Actinomyces scabies*) was conducted at Canberra. Ontario and United States seedling 6344 showed the highest resistance of the seven varieties tested; Russet Sebago was slightly more resistant than Sebago, but less resistant than Ontario or 6344. Menominee appeared less resistant than in the previous season's trial.

(ii) Rhizoctonia solani.—In a pot experiment, a single potato variety was grown in a number of different types of soil under uniform conditions of temperature, soil moisture, and inoculation with a single pathogenic strain of *R. solani.* The amount of sprout injury did not vary significantly in the different soil types, which ranged from infertile sand to rich, heavy, alluvial loam.

(iii) *Late Blight.*—Further tests of a number of blight-resistant potato hybrids from Scotland and Canada against eight isolates of *Phytophthora infestans* from New South Wales, Tasmania, and Victoria gave no evidence that more than one strain of *P. infestans* was included amongst the eight Australian isolates tested.

(*e*) *Pasture Diseases in the Ninety-mile Plain, South Australia.*—These were investigated in co-operation with the Division of Biochemistry and General Nutrition. Very stunted or almost bare patches, with well-defined edges, appeared in pasture on sandy heath soil soon after germination. Two distinct types of patch occurred. In one, the roots were rotted by soil fungi, including *Rhizoctonia, Pythium, Fusarium,* &c. In the second type, eelworms (*Heterodera* sp.) were plentiful in the roots, subterranean clover being severely affected.

In both types of patch, no consistent differences were found between affected and unaffected soils in pH, total soluble salts, or sodium chloride. The pH ranged from 6.7 to 8.7. The zinc content of clover from affected areas tended to be lower than that of parallel samples from normal areas, but it is not thought that the differences were large enough to account for the stunting in the absence of other causal factors.

(*f*) *Antibiotic Investigations.*—Screening of soil microflora for antagonistic mircro-organisms has now been placed on a routine basis. To April, 1951, a total of 78 antagonistic isolates has been obtained. Of these, 12 are actinomycetes and work is being concentrated on this group. Screening will be continued with media which are at least partially selective for actinomycetes.

Preliminary selection studies, involving spectrum and potency tests, are in progress on actinomycete isolates, to allow evaluation of isolates against both fungal and bacterial plant pathogens as a basis for selection of organisms promising enough to warrant developmental work. Two such organisms have already been selected.

Arrangements have been made for co-operation with antibiotic workers at the Commonwealth Serum Laboratory in screening the Australian soil microflora for antibiotic-producing actinomycetes.

An investigation of the effect of actidione on cherry fruit showed that concentrations of 1, 5, 10, and 25 p.p.m. had no phytotoxic effect and caused no storage injury to fruit under the conditions of the experiment. This material has been reported by various American workers to be very effective in the control of cherry leaf spot caused by *Coccomyces hiemalis,* but no information on possible fruit injury has been available.

(*g*) *Brown Rot of Stone Fruits.*—During the past three years great contrasts in the amounts of brown rot in adjoining trees have been repeatedly observed in Canberra. The evidence suggests that the factor responsible for the variation in disease incidence is in the immediate environment of each individual tree. The trend of disease incidence over the last three years in individual trees is towards increasing percentages of rot in successive seasons. Attempts to increase the amount of brown rot in an apricot tree by introducing extra inoculum before and during ripening in two successive years failed to increase the incidence of the disease.

(*h*) *Seedling Blight of Peas.*—The inherent character of some soils may not be as suitable as that of other soils for pea seed germination. The disease-producing capacity of the pathogen in one soil may be different from the disease-producing capacity of the same species of organism in another soil. Applying water to a damp soil after sowing peas may result in greater loss from seedling blight than applying the same total amount of water in one application to a dry soil. Stirring the soil immediately before sowing, to distribute the moisture evenly, results in a higher percentage emergence than from unstirred soil.

A steamed soil when infested with the sand fraction gives more seedling blight than when infested with the colloidal fraction of an unsteamed soil. The pathogen can be easily isolated from plates sown with a portion of the sand fraction. It has not yet been found on plates sown with the finest colloidal fraction. Relatively few bacteria are associated with the sand fraction of a soil. The average of the numbers associated with the colloidal fraction is 30 times greater than the average numbers in the sand fraction.

(*i*) *Take-all of Wheat.*—Since the last report was made concerning take-all of wheat, two experiments, each of four years' duration, have been completed.

The evidence is that the control of take-all by fallowing is by modification of the effects of the disease in infected plants. Induced resistance appears to be the result of greater availability of nutrients in the fallowed soil. Some superimposed fertilizer treatments may be associated with an improved condition of the roots at harvest time, others with the opposite effect. These differences in root conditions are not reflected in the yields.

With various fertilizers it was shown that the condition of the roots at harvest time, the grain yield, and total weight of plants, were all better in the soil to which a culture of *Ophiobolus graminis* was added than in the control soil. The addition of superphosphate to the soil used in the experiment was without effect on yield or on root rotting. The combination of nitrogen, potassium, phosphorus, calcium, and magnesium gave the most satisfactory results over the four-year period.

5. Fruit Investigations.

The work in the Division is confined mainly to apples and pears and is carried ont at Stanthorpe and Tasmania.

Work on vine and citrus fruits in progress at Merbein and Griffith is outlined in Chapter IV., and investigations into insect pests are described in Chapter IX.

(*a*) *Apple and Pear Investigations, Stanthorpe, Queensland.*—Work at the field station at Stanthorpe is concerned primarily with apple and pear rootstocks and stock-scion relationships. Investigations are designed to discover rootstocks which give a better performance under Australian conditions than the commonly used stocks, are easily propagated, and are immune to attack by woolly aphis.

Crops on the main experiment plots were light dnring the 1950-51 season as a result of very unfavorable conditions which obtained during the blooming period. The comparative yields of the various rootstocks and treatments, however, were in conformity with results previously reported.

In another apple rootstock trial planted during the winter of 1950, eleven new woolly-aphis-immune stocks budded to Jonathan are being tested against Northern Spy. These new immune rootstocks were bred at the East Malling Re-earch Station in England.

A further five acres of land has been prepared for the planting of another trial during the present winter. In this trial four Merton stocks which gave excellent results in an eight-year nursery trial previously reported, together with a local selection 84, budded to Delicious, will be tested against Delicious on Northern Spy and Delicious on its own roots. Some of these stocks have been distributed to nurserymen. Other nursery trials and small experimental rootstock plots are being continued.

In studies concerned with the problem of replanting, soil analyses and experimentation have shown that it is most unlikely that an accumulation of arsenic in the soil, from continued lead arsenate sprays, is responsible for the difficulty encountered in re-establishing trees on old orchard land. It has been found that apple seedlings fail to grow normally in soil infested with the nematode *Pratylenchus pratensis,* which has been found in the Stanthorpe district.

(*b*) *Apple Investigations in Tasmania.*—(i) *Physiological Disorders of Storage.*—Work in Tasmania over a number of years sought to discover the causes of the various physiological disorders which occur in apples during common and cool storage and what orchard factors affected the incidence of these disorders. The most important single factor was found to be the size of the crop from which the fruit was derived and the size of the individual fruits. Investigations now in progress seek to ascertain the differences which exist in the mechanism of post-harvest development in fruit from large and small crops. In the first place a detailed examination is being made of certain varieties of apples selected to cover a wide range of such varietal characteristics as inherent size of fruit, period of maturation, and susceptibility to disorders. Fruit of these varieties both from trees carrying large fruits and from trees carrying small fruits are being examined for respiration rate, cell size, total and free acid, and total and soluble nitrogen. Total and soluble nitrogen

is also being determined in the leaves. In the second place, similar examinations are being made at intervals during the development of the fruit from large-fruited and small-fruited trees of the one variety. This work is complementary to work being done by the Division of Food Preservation (*see* Chapter XII., Section 8 (*b*)). It is designed to determine how varietal characteristics may be correlated with fruit physiology and how this is affected by mean fruit size, cell size, nitrogen status, and mineral status.

(ii) *Problems of Gas Storage.*—It is believed that the apple industry in Tasmania is approaching the situation when gas storage might become economic. No information is available on the behaviour of Tasmanian apples in gas storage except that obtained indirectly in investigations of the disorder known as Brown Heart. A beginning has therefore been made with preliminary tests and during the 1951 season the behaviour of the varieties Cleopatra, Tasman Pride, Jonathan, Granny Smith, Delicious, Golden Delicious, and Democrat in concentrations of carbon dioxide of 5 per cent. at 33° F. is being examined.

(*c*) *Seed Potatoes.*—A potential market for Tasmanian potatoes exists in Rhodesia if they could be landed in satisfactory condition after the end of September. In co-operation with the Tasmanian Department of Agriculture investigations during 1949 and 1950 were made on the effect of cool storage and chemical treatment on the subsequent sprouting of seed potatoes. It was desired to delay sprouting between the time of digging and the date of shipment in early September without unduly inhibiting subsequent sprouting. Tests showed that for three of the varieties, viz. Up to Date, Medium and Late Brownell, storage at 36° F. for eight weeks effectively delayed sprouting but did not affect subsequent germinations on planting. Treatment with chemical germination inhibitors such as "Fusarex" was effective in retarding sprouting in the post-cool-storage period if applied after the cool-storage treatment but not if applied at its commencement.

6. Drug Plants.

(*a*) *Survey of Native Plants for Substances of Pharmacological and Chemical Value.*—This survey has continued on the basis outlined in earlier reports, materials selected by means of field tests being passed to collaborating Universities for further examination. Some results are reported by the Division of Industrial Chemistry (*see* Chapter XVII., Section 7).

During the year some 600 additional preliminary tests were made of native species for the presence of alkaloids, saponins, cyanogenetic glycosides, and other chemical principles, and some 250 bulk samples of material were collected and forwarded to the chemical laboratories for more detailed examination. The new species found to contain alkaloids were in general distributed among the families and genera in much the same proportion as previously reported, but a higher proportion selected for testing were derived from those families and genera now known to be rich in these substances. Fifty species have now given positive tests for the presence of cyanogenetic glycosides and 70 for a substantial content of nitrate. Both hydrocyanic acid and nitrate may be responsible for the poisoning of live-stock. Some 200 species by giving positive reactions both to the froth test and the Liebermann-Burchard test have now been shown to contain saponins. The results of all preliminary tests have been collated and prepared for publication. Routine tests for proteolytic enzymes have been abandoned because no satisfactory testing arrangements could be made. Certain local species of such families as the Euphorbiaceae, Moraceae, and Apocynaceae have been found to have strongly proteolytic enzymes.

Substances derived from the survey continue to be examined for the possession of anti-mitotic activity in connexion with the search for materials having anti-tumour properties, and substances so selected are forwarded to the Sloan Kettering Institute for Cancer Research, New York, for testing as anti-cancer agents. Unfortunately no positive results with these materials have yet been obtained.

As part of the survey much information is being accumulated with respect to the variations in alkaloid type and amount in certain local species, the correlation of the chemistry and taxonomy of species, and the ecology of the areas, particularly the rain-forest areas, covered.

(*b*) *Opium Poppy* (Papaver somniferum).—It was reported last year that the programme of selecting and breeding varieties which gave a high yield of morphine and were suited to Australian conditions of cultivation had been completed. During the past year bulk seed supplies of seven of the improved types have been built up. It is proposed to hold these seed stocks against possible requirements in the future.

(*c*) *Duboisia Spp.*—The work of assessing the relative value of previously selected strains of the native species *Duboisia myoporoides* and *Duboisia leichhardtii* and natural and artificial hybrids between these two species as sources of atropine and hyoscine under cultivation has been continued. Progress has been hampered by the necessity of further improving the methods of chemical assay to permit more rapid and quantitative determinations of the alkaloid content of samples. During the year the column chromatography method has been developed to a stage satisfactory for the recommencement of the assay of experimental material.

It has been shown that certain of the seven strains of northern-type *D. myoporoides* which have been critically examined yield hyoscine in greater amount and more consistently than the others. Further selections from the area of occurrence whence these superior strains were derived have been made. It is anticipated that at least four high-yielding hyoscine-bearing clones of diverse vegetative type will be obtained from this work.

Considerable variation in vegetative characters is apparent between the clones of the southern-type, hyoscyamine-yielding *Duboisia myoporoides*. Some are very vigorous and heavily leaved. Further evaluation of these types and the clones of *Duboisia leichhardtii* cannot be made until chemical analyses are completed.

A large block of F1 plants of crosses *D. myoporoides* and *D. leichhardtii* was planted in 1949 with typical *D. leichhardtii* and *D. myoporoides* plants for comparison. The hybrids made much better growth than either parent species and regrowth after pruning in October, 1950, was also more vigorous in the hybrids. Clones of a number of the more vegetatively attractive natural hybrids, several F1 plants of northern *D. myoporoides* and *D. leichhardtii*, and the F1 of a suspected cross between southern *D. myoporoides* and *D. leichhardtii* have been set out in randomized blocks for comparison. The F2 of the northern *D. myoporoides* and *D. leichhardtii* cross has produced trees which are vegetatively outstanding. Information with respect to the alkaloids of this material is not yet available.

7. Tobacco.

Experimental work was continued in the Ayr, Queensland, district in association with the Queensland Department of Agriculture and Stock. The programme was severely affected by unseasonal rains and wind during November and the plots at Clare had to be

abandoned. According to Ayr records a similar or higher rainfall during November has occurred on only two occasions over a period of 64 years. The plots established in southern Queensland for the study of varietal characteristics were also destroyed by storm rains and winds.

The Thirteenth Conference of Commonwealth and State Tobacco Technical Officers was held at Ayr at the end of November. Reports on the experimental work in progress throughout Australia and on results obtained were submitted and crops and experiment plots in the district inspected. Major topics discussed were diseases, insect pests, irrigation, soil fertility, and possibilities for increased production.

(*a*) *Irrigation.*—At Clare, the results of the two previous seasons' investigations on water requirements of tobacco showed that yield and quality were maintained over a relatively wide range of treatments. With adequate soil moisture it appeared that other factors such as quantity of nitrogen available for growth and the number of plants per unit area were of particular importance. Accordingly the effect of three levels of nitrogen and three rates of planting on quality was investigated. Differences in growth were apparent but the destruction of the plots just before harvest precluded the possibility of obtaining substantive data. The experiment will be repeated in the coming season.

(*b*) *Genetics.*—The study of varietal characteristics undertaken at Clare during 1948 and 1949 was continued at Inglewood in southern Queensland, where ten varieties were established in replicated plots. Seasonal conditions were very unfavorable and the plots were washed out by rains and wind storms. At Ayr, the breeding programme for mosaic resistance was continued and resistant lines of flue-cured tobaccos from the United States of America were also tested.

(*c*) *Diseases.*—Under greenhouse conditions transmissions of yellow dwarf and big bud viruses of tobacco by grafting were obtained more readily in summer than in winter. Nevertheless the percentage of successful transmissions was relatively low. As the insect vector is even more unreliable, further attention is being given to alternative host plants, particularly of the yellow dwarf virus, to determine relative susceptibility to infection. Preliminary results indicate that wide differences in the time interval between grafting and appearance of symptoms occur between different species of *Nicotiana*. This factor is being used as an indicator of relative susceptibility and very susceptible species can be expected to give more reliable results in experiment work while resistant species may be useful in the development of resistant commercial types. Further attempts to transmit yellow dwarf by dodder have been unsuccessful. Investigations on the insect vector, its feeding habits, and its ability to transmit the virus under different conditions are being continued by officers of the Division of Entomology (*see* Chapter IX., Section 10).

(*d*) *Chemistry.*—Investigations have shown that factors conducive to loss of sugars and allied compounds in flue-cured tobacco result in poor-quality leaf. Sugar contents of the order of 0-5 per cent. occur in low-quality, "trashy" leaf compared with 30 per cent. or more in good leaf. Values are high for total nitrogen, protein nitrogen, and ammonia nitrogen and low for amide nitrogen in trashy leaf. Weight per unit area is 30-50 per cent. less than good leaf. As similar results are obtained with ripe, uncured leaf dried at a high temperature immediately after harvesting, curing methods are not responsible for the occurrence of trashiness. It is due to the conditions under which the plants are grown. Nitrogen supply, temperature, and amount of sunshine appear to be most important factors. With high nitrogen, high temperature, and low sunlight, carbohydrates, essential oils, polyphenols, and yellow pigments are degraded and used up by the plant.

The degree to which small changes in sugar content can be measured is under investigation. Estimations on a routine basis can be made on plant samples containing 50 mg. of sugar while samples containing 1 mg. or less can be estimated by colorimetric methods.

(*e*) *Other Investigations.*—At Katherine, Northern Territory, attention was concentrated on seedling production, the object being to determine methods by which seedlings can be grown at any time of the year. Soil sterilization is essential, as is also an adequate supply of nitrogen. Provision must be made to avoid loss due to heavy storm rains in the wet season and to high temperatures during the latter part of the year. Small field plots to determine the best period of the year for commercial production are being established.

8. Plant Physiology.

Because of accommodation difficulties in Canberra the Principal Physiologist has been stationed at Adelaide. The work of the Physiology Section in Adelaide is chiefly concerned with studies of plant growth and development of the related mechanisms associated with such development. Most economic crops produce their commercial harvest (seed or fruit) only after flowering, which may be considered the apex of a plant's development. However, other important crops, e.g. pastures and tobacco, are, in the main, at their best when held at the vegetative condition, which is the inverse of flowering or reproduction. Thus information on the factors leading to flower initiation may ultimately achieve considerable significance as an aid to controlling this important process.

Physiological studies in Canberra are concerned chiefly with the growth and development of tobacco, and the inhibition and stimulation of embryonic tissue.

(*a*) *Photo-period Studies.*—Two experiments were performed to determine suitable plants for photo-period studies. Desirable characteristics are smallness, to conserve valuable space in controlled environment equipment, and a short life cycle.

(i) *Long-day Plants.—Echium plantagineum* L. (Salvation Jane, Patterson's Curse) was shown to be a long-day plant. Under days artificially shortened to nine and a half hours the plant remained vegetative for more than 100 days; under days artificially lengthened to eighteen hours the plants produced microscopic flower primordia 21 days after sowing. Plants grown under short-day conditions could be induced to flower primordia formation by exposure to only six to eight long days. *Malcomia maritima* R.Br. (Virginian Stock), which is a small garden annual, similarly behaved as a long-day plant, but is less desirable as experimental material in that the flowering responses are obscured by low temperature conditions.

(ii) *Short-day Plants.—Xanthium californicum* Greene (Californian burr) and *Xanthium pungens* Wallr. (Noogoora burr) remained vegetative when the days were artificially lengthened to eighteen hours, but promptly initiated flower primordia when the days were shortened to eight hours. *X. pungens* required six exposures to short day, *X. californicum* only two. The latter should be valuable material for such studies, comparing most favorably with *X. pennsylvanicum*, which needs only one exposure and in this respect is the most sensitive plant known.

(*b*) *Hormone Assay.*—Modifications to existing assay methods have been worked out. In the *Avena* method grain size has been shown to have an effect and the reasons for it established.

(*c*) *Effects of Soil Moisture and Drought on the Growth of Tobacco.*—The tobacco-grower has long considered that a drought adversely affects the yield

and quality of the tobacco leaf. The tobacco plant, however, can recover remarkably quickly from a wilted condition. The reduction in yield caused by different exposures to drought was slight (up to 9 per cent.) as compared with the reduction (up to 70 per cent.) when the plants are grown in soil maintained at levels of moisture below the water-holding capacity. With high soil moisture, rate of leaf formation is increased and/or onset of the reproductive phase is delayed and thus yield is increased.

(*d*) *Rate of Aging and Leaf Shape of Tobacco.*—There is a definite gradation in the shape and area of the individual leaves and the rate of change in the shape or area of the successive leaves gives a quantitative measure of the rate of aging. Shape, being related to maturity of the plant, can be used as an index of the stage of development. Thus, the plant breeder could determine earliness and lateness quite early in the ontogenetic cycle.

(*e*) *Stimulation of Bud Growth and Tobacco Leaf Culture.*—Individual leaves are being cultured and can be utilized in the studies of leaf expansion and nutritional disorders. Such leaves nearly always become distorted by interveinal areas growing more than the veinal system, whereas expansion during growth of the normal leaf results in a reasonably flat mature leaf. These changes are considered to be associated with auxin distribution.

(*f*) *The Inhibition of Bud Growth in Tobacco Suckering.*—Sucker growth has been effectively controlled under glasshouse conditions by applying synthetic growth regulators to the "topped" plants as a substitute for the natural hormone which maintains the apical dominance in "untopped" plants. Some mineral oils of American origin have also given promising results under glasshouse conditions. A preliminary field trial in Queensland was so severely damaged by storm and rain that little information was obtainable from the surviving plants. It is hoped to repeat the experiment this coming season.

(*g*) *Stimulation of Bud Growth in Wheat—Tillering.*—The variety Bencubbin has been sown at Canberra to determine the effect of some growth regulators on tillering, weight of grain, and yield.

9. Pasture Investigations.

Most of the Division's work in this field is carried out at the various regional centres, but certain investigations are being undertaken on a co-operative basis with State Departments of Agriculture at their Experimental Farms and on private properties. Australian pastures can broadly be divided into three ecological units, an area of Mediterranean climate with a dominant winter rainfall, an area of more or less uniform rainfall, and an area of summer rainfall, and for this reason experiment stations have been established in each ecological zone.

The investigational work can be divided into—

(i) Ecological studies on native pastures, which include regional surveys, grazing management trials, and regeneration studies.

(ii) Ecological studies of exotic pastures, including the selection and establishment of species and their management under natural rainfall and irrigated conditions.

(iii) Nutrition, including the study of soil deficiencies.

(iv) Chemistry, including the use of pastures under land use and fertility maintenance.

(v) Genetics, a phase of the work which will be developed in the coming year.

Of the Australian pasture species, which are relatively limited in number, subterranean clover is the most important pasture legume for grazing because it has the most widespread distribution over climates and soils. As there are important soil deficiencies in all the major pasture areas of Australia, detailed studies of the nutritional requirements of this species are being continued under field, greenhouse, and laboratory conditions.

Although a large part of the work is concerned with sheep pastures, the problems of pastures for cattle are being given attention particularly in the northern zone of summer rainfall.

Attention has been given to the control of weeds by chemical methods, especially mintweed, skeleton weed, and hoary cress.

Insect pests of pasture such as cockchafer grubs are being studied by the Division of Entomology and this work is reported in Chapter IX.

10. Pasture Investigations at Canberra.

(*a*) *Pasture Plant Studies.*—At the Dickson Experiment Station a trial is in progress to measure the productive capacity of natural grassland and an improved pasture of phalaris and subterranean clover in terms of livestock products. On the improved pasture for the past four years, three times as many sheep have been carried and fleece weights have been increased by approximately 10 per cent. Accurate records of herbage production are being kept and botanical changes in the pastures are recorded and will be correlated with rates of stocking and other known environmental factors.

To determine whether production from phalaris can be further increased, it is being tested in spaced rows of 7 in., 21 in., and 35 in. with subterranean clover, and in another trial species have been added to the mixture to ascertain if extra production can be obtained at times when phalaris is normally unproductive. The additional species being used are *Bromus coloratus, Bromus inermis, Bromus marginatus, Bromus mollis, Festuca mairei, Poa iridifolia, Agropyron cristatum, Phalaris arundinacea,* and *Phalaris aquatica,* all of which have a different growth rhythm from *Phalaris tuberosa.*

From a large number of introduced species of medic, selections of those with non-objectionable burrs have been made and are being tested at various centres for productivity and ability to build up soil fertility. At Wagga and Temora, on red-brown soil, varieties *Medicago hispida terebellum* and *M. hispida reticulata* have given greater production than ordinary burr medic and show little tendency to adhere to the wool of sheep. *M. tribuloides*–173 has outyielded ordinary commercial lines of barrel medic. Seed stocks of these superior types of medic are being built up and made available to State organizations for wide-scale testing. Investigations on Wimmera ryegrass-subterranean clover pastures have demonstrated the marked increase in grass content that follows increasing use of superphosphate.

(*b*) *Soil Fertility Studies.*—At the Dickson Experiment Station a trial is in progress to determine the influence of three types of pasture, viz., volunteer, subterranean clover, and a mixture of phalaris and subterranean clover, on soil fertility after varying periods of time ranging from two to eight years. As it will be necessary to repeat the trial at least twice, final results will not be available until 1964.

Trials are in progress to study the processes by which nitrogen is returned to the pastures both directly from the decay of vegetative tissue and indirectly through the animal in the form of excreta.

(*c*) *Plant Nutrition Investigations.*—Further work on the nutrition of pasture plants on the Southern Tablelands of New South Wales is in progress.

Studies to examine the residual effect of phosphorus on sown pasture have been continued. The first cycle of the field trials commenced in 1946 was completed in 1949. These trials are being maintained for a further four years. Current data support the results of the first cycle in that the total yield of pasture is determined by the total amount of superphosphate applied in the period. Further work with phosphorus includes a study of the phosphorus requirements of plants grown on soils of differing nitrogen status.

A previous report suggested that sulphur as well as phosphorus, both major constituents of superphosphate, are required in combination for normal plant growth on soils of the Southern Tablelands. Current work has shown that a response by plants to dressings of sulphur alone can occur in the field. Work is now in progress to determine both the local intensity and the geographical extent of deficiencies of sulphur and phosphorus.

Marked responses to molybdenum dressings still occur where levels of only 2 oz. of molybdenum trioxide per acre were applied in 1946. Further nutritional studies with molybdenum are in progress. In particular, the effect of artificial fertilizers on molybdenum uptake by plants is being studied.

During 1951 the Agrostology Section has undertaken a co-operative programme of work with the Victorian Soldier Settlement Commission and the Victorian Department of Agriculture, the aim of which is to determine the nutrient requirements of pasture grown on grass-tree and forested areas of Heytesbury County, Victoria.

(*d*) *Vegetation and Pasture Survey.*—The mapping of the vegetation of a portion of the south-west slopes and adjacent plains of New South Wales has been completed. It has now been established that the disclimax savannah communities in the western portion of the region have been developed from two associations, the *Acacia pendula* association on the red-brown earths in this region and the *Atriplex nummularia* association on the grey and brown soils of heavy texture.

Some relationships between the vegetation and the pH and water-holding capacity of the soils have been determined. Other investigations of soil factors in relation to vegetation are being made.

(*e*) *Toxaemic Jaundice Investigations.*—Co-operative work with the Division of Animal Health and Production has been continued (*see* Chapter VII., Section 15 (*b*)). The botanical composition of irrigated subterranean clover pastures at Cobram is being determined at monthly intervals.

(*f*) *Pasture Chemistry.*—Investigations are being made into factors concerned in the relative distribution of subterranean clover (*Trifolium subterraneum*) and *Medicago* species which appear to be governed in some way by soil pH. Earlier expectations that this may be governed by phosphate availability have been proved unlikely. Experiments are being made to determine whether the calcium carbonate content of the soil is the dominant factor.

A detailed examination of the copper, manganese, molybdenum, and zinc content of oats in relation to soil type and stage of growth in a pot-culture experiment shows that the concentrations within the plant vary according to the availability of the elements but the general pattern of distribution of the elements within the plant is unaffected by soil type.

A method has been developed for the rapid determination of sulphur in plant material. This method involves the digestion of the sample with a mixture of concentrated hydrochloric and nitric acids and a small amount of sodium chloride in the presence of selenious acid as a catalyst. After boiling with dilute hydrochloric acid to prevent interference from selenic acid and filtration the sulphur is estimated turbidimetrically as barium sulphate.

11. Pasture Investigations at Trangie, New South Wales.

The Organization's new Mitchell Laboratory at the Trangie Experiment Farm was officially opened on 23rd May, 1951, and its facilities will be of great assistance in the conduct of the co-operative grazing trial. At this centre, although some attention is being given to the introduction of better pasture species, most of the investigational work centres upon the study of native pastures.

Six hundred and eighty square miles have been surveyed and classified into types, and information on past management has been gathered so that reasons for certain changes in botanical composition can be advanced. Stages in degeneration on the several soil types with increasing intensity of stocking can be recognized. As the rate increases, Liverpool Plains grass (*Stipa aristiglumis*) gives way to fairy grass (*Sporobolus caroli*) and corkscrew grass (*Stipa setacea*), and finally the pastures become dominated by windmill grass (*Chloris truncata*).

The deterioration to a stage of *Stipa-Chloris truncata* codominance that is evident in many places can now be positively correlated with a mean rate of stocking of one sheep per acre for the past 20-30 years.

Certain areas have been fenced off from stock and details are being gathered on the nature and rate of regeneration in order to determine the most economical method of restoring degenerated native grassland.

The grazing trial on pasture typical of about 350 square miles of light land in the Trangie area which is being conducted in conjunction with the New South Wales Department of Agriculture is now in its fourth year. The objects of this trial are to determine appropriate rates of stocking and methods of grazing management to maintain a good admixture of annual and perennial grasses in the sward, and to obtain fundamental information on meat and wool production under known conditions of grazing on this type of pasturage.

Despite the general improvement that has occurred as a result of good seasonal conditions, the basal cover of the perennial species is becoming relatively greater at the lower rate of stocking (one sheep to two acres), indicating that useful information will be forthcoming from the trial in regard to rate of stocking.

The excessive rain which occurred last year disclosed that *Stipa* spp. were more sensitive to flooding than some of the other native grasses and necessitated certain changes in the layout of the experimental area.

12. Pasture Investigations at Deniliquin, New South Wales.

(*a*) *Native Pasture Studies.*—Further excursions towards the *Atriplex vesicaria* association have been made and 24,000 acres of pastures have been mapped. Pastures are being defined and changes brought about by different systems of grazing management are being observed.

The grazing trial on native pastures has been continued. Owing to very heavy rains in the first half of the year annual species were prolific but seeding occurred at the same time as in the 1949-50 season. The growing period of the perennial was not extended.

Probably owing to competition from annuals, the number of perennial grass seedlings was much lower than in the previous year. It has been observed in two seasons that the survival of perennial grass seedlings varies according to species and the interaction between

species and grazing intensity. The data for survival of more mature plants do not yet indicate any significant change due to these factors.

The total basal cover has been reduced on the ungrazed and heavily grazed treatments and has increased under the medium stocking rate. The basal cover of *Danthonia semiannularis, Stipa falcata,* and *Chloris truncata* has been reduced on the ungrazed and on the heavy grazing treatments. *Sporobolus caroli* has not been affected in basal cover by the treatments.

The amount of green material available for grazing is at a maximum in October and a minimum in January. The highest yield of green forage is obtained in the light and medium grazing treatments. There is a trend, with heavy grazing treatment, towards higher yields of certain annual species, particularly *Calocephalus sonderi* (poverty weed).

The seasonal weight variation in the sheep flock has been small, and the mean body weight this season has been higher than last.

(*b*) *Introduced Plant Species and Strain Trials.*—(i) *On Red-brown Earth of Coarse Texture.*—High yields were obtained under dryland conditions in 1950 because of the early break and long effective rainfall period of ten months. Lucerne, *Medicago tribuloides,* and Bacchus Marsh subterranean clover outyielded other legumes in a row trial on levee soil. *Phalaris tuberosa, Ehrharta calycina,* and *Agropyron obtusiusculum* were the most productive grasses.

Under summer irrigation seed yields of 1,200 lb./acre were given by guar (*Cyamopsis tetragonaloba*) grown at a 7-in. row spacing, compared with 500 lb./acre at a 20-in. row spacing. Wimmera ryegrass was by far the most productive grass to be grown in association with subterranean clover under supplemental autumn and spring irrigation. *Phalaris tuberosa, Festuca pratensis,* and *Festuca elatior* may be of use in extending the length of the growing season. Subterranean clover was the most productive legume to be grown in association with Wimmera ryegrass. Clare and Bacchus Marsh strains were ten times more productive than Dwalganup and three times more productive than Mount Barker. In a summer irrigated sward trial Hunter River lucerne and Ladino white clover were the best legumes.

(ii) *On Grey Soil of Heavy Texture.*—Forage and green manure species to show promise in a row trial under summer irrigation on heavy soil have been *Pennisetum purpureum, P. glaucum, Sorghum almum, Panicum coloratum, Cajanus* spp., *Sesbania* spp., and *Vigna unguiculata. Trifolium fragiferum* and *Paspalum dilatatum* are the most promising recognized perennials.

(*c*) *Irrigated Pasture Studies.*—(i) *Establishment.*—Low brairding percentages of small-seeded pasture species are commonly recorded on the heavy-textured, readily-dispersed, plains soil. Surface sowing increased the brairding percentage by 25 per cent. of that obtained from sowing at a shallow depth.

The establishment and survival of *Phalaris tuberosa* in its first year was studied at three density levels ranging from 10 to 50 plants per yard of drill row. Tiller number was halved by a fivefold increase in density. Percentage mortality occurring from spring until mid summer was greater at high than at low or medium density.

(ii) *Fertilizer Trials.*—Blood manure, sodium nitrate, and ammonium sulphate had no effect on the yield of subterranean clover grown alone, but all increased the yield of Wimmera ryegrass alone. Yield increased with increasing rates of application of each fertilizer. Blood manure at 6 cwt./acre doubled the yield of ryegrass, ammonium sulphate and sodium nitrate increased it by three to four times. A diffusion extract from ryegrass contained less phosphate on plots receiving ammonium sulphate than on plots receiving other nitrogenous fertilizers or no nitrogenous fertilizer.

Superphosphate caused a progressive increase in the yield of pasture when applied in amounts ranging from nil to 4 cwt./acre. The increase was almost entirely due to the subterranean clover component. The phosphate content of a diffusion extract from both species was increased on the plots receiving superphosphate.

Slaked lime at 1 ton/acre mixed with superphosphate decreased the yield of subterranean clover compared with its yield on plots receiving superphosphate alone. A diffusion extract from clover on plots receiving slaked lime tended to contain less phosphate than that from other plots.

(iii) *Soil Structure and Root Growth Studies.*—Quantitative data on root growth showed that the dry weight of roots found from 0 to 18 in. after three years' growth of perennial pastures ranged from 8 to 14 tons/acre. From one-half to three-quarters of this amount occurred in the surface 3 in. Total herbage yields over the two years previous to sampling ranged from 0.4 to 0.9 of the root weights found.

An experiment is in progress to determine the effects of a rice crop grown with and without gypsum on the properties of a clay soil and on subsequent pasture growth. Gypsum at 2 and at 8 tons/acre increased the brairding of the crop by 50 per cent. The higher density of plants on gypsum plots persisted to maturity, but total yields were not increased in the same ratio as densities because of a compensatory decline in dry weight per plant. Gypsum increased the depth of water penetration and decreased the apparent density of the soil under crop.

(*d*) *Irrigation and Soils Studies.*—(i) *Infiltration.*—The method of expression of infiltration into soil has received increasing attention in recent years. Rate of entry of water into soil is greatest at the beginning of an application, and decreases with time, tending towards a constant value. The infiltration of the first few inches of water is important in irrigation practice with pastures. This "initial" infiltration rate is affected by moisture content of the soil at the time, and experiments were conducted to obtain the relationship between antecedent soil moisture and "initial" infiltration. The regression equations which have been derived have been used for correcting infiltration measurements from various treatments on a soil type, adjusting them to the mean soil moisture level.

(ii) *Permanent Wilting Point.*—The method of Veihmeyer and Hendrickson, using sunflowers as an indicator plant, has proved unsatisfactory for some fine-textured Riverina soils. Experiments have been made with the method of Breazeal and McGeorge, using soil in glass tubes surrounding stems of tomato plants to develop adventitious roots.

(iii) *Irrigation Hydraulics.*—Some preliminary trials were made with the water measuring unit designed and constructed for determining the relationship between flow, slope infiltration, and ground cover when irrigating pastures by border-check irrigation. By maintaining the factors of slope, width of bay, and ground cover constant during various flows, and taking data of flow, infiltration, and water depth at fixed reference points during flow periods and after its cessation, an approach is being made to the mathematical relationship between these factors.

(iv) *Consumptive Use of Water.*—Following the presentation of data during last season, more precise sampling and water measurement recording are being undertaken to obtain differences for soil and types of pastures.

(e) *Chemical Studies.*—Work has been intensified on the determination of changes in total soluble salts, chloride, and pH resulting from the irrigation of a number of types of pastures on the two major soils of the field station, and further observations have been made on the degree of soil dispersion resulting from irrigation.

Further studies on irrigation water quality show that there is little variation in conductivity and salt content as the irrigation season advances. The irrigation water may contain 50 p.p.m. of colloidal clay, adding between 3 and 4 cwt. of this material per acre at each irrigation. It has been determined that up to 0.7 per cent. of applied phosphate might be removed in drainage water from the first three irrigations after application. Only traces of ammonium and nitrate-nitrogen were found in the drainage water from irrigation bays.

An initial approach was made to fractioning the fixed and residual phosphate available from two soils.

13. Pasture Investigations at Armidale, New South Wales.

(a) *Grazing Management Studies.*—In three experiments on typical native pasture, a study is being made of the effect on the sheep and on the pasture of different rates of stocking, continuous versus rotational grazing, and size of flock. These investigations are being made in co-operation with the Division of Animal Health and Production (*see* Chapter VII., Section 19 (e)) and accurate records are being maintained in respect of the following:—(i) infection by internal parasites; (ii) wool production; (iii) live weight, growth, and behaviour of the sheep; (iv) yield and botanical composition of the pasture; and (v) chemical composition of the pasture.

The experiments are now in their third year, and the pasture under the heavy grazing treatment is showing a slightly lower amount of total forage present than under the medium and light grazing treatments. No differences are being recorded in the amount of forage present under continuous and rotational grazing. The fluctuations in amount of total forage present due to grazing treatments and seasonal conditions appear to bear no relationship to variations in sheep body weight or wool production and it is probable that these variations are due to the varying amounts of the green forage content of the pasture. The proportion of green forage is very small and with the techniques employed so far it has not proved possible to measure accurately these small amounts of green forage.

No differences have yet been recorded in the amount of total forage present under grazing by different sizes of flock when each is grazed at the rate of one sheep per acre.

(b) *Plant Species and Strain Trials.*—Production and the general agronomic characters of a range of pasture species are being compared, both in rows and in swards, at the "Chiswick" Field Station, as well as at various other centres in the New England region.

The exceptionally wet and mild winter conditions of 1950 resulted in high production by a number of species.

In row trials, *Phalaris*, *Festuca*, and *Dactylis* species and strains were again very productive, while *Bromus inermis* strains yielded well in the spring. Of the legumes, subterranean, red, white, and crimson clovers were outstanding at all centres. In the sward trials under intermittent common grazing, the best grasses have been the tall fescues, phalaris, and cocksfoot. Ryegrasses, which were productive initially and then declined, have begun to improve. Tallarook subterranean clover has made excellent winter and spring growth, while red clover has yielded best in the summer. White clover has made good spring and summer growth, but lucerne has given poor results when sown with grasses under sward conditions.

On "Chiswick", in a three-years-old subterranean clover variety trial, which was stocked at the rate of five sheep/acre during the winter of 1950, Tallarook again set large quantities of seed but was almost equalled in forage production by Bacchus Marsh and Mount Barker varieties. However, at two other centres, on granite soils, Tallarook far outyielded Mount Barker in both forage and seed production.

A species trial sowing near Bundarra in 1949 was repeated on other granite soil areas at Inverell and Glen Innes in 1950. At Bundarra, Tallarook subterranean clover yielded well, as did also phalaris and white clover. Tallarook, red, and white clovers did well at Glen Innes but an unknown soil deficiency caused a partial failure at Inverell.

During 1950 very high stocking rates were obtained on some pastures on "Chiswick". A three-years-old stand of phalaris-white clover carried 9.8 sheep/acre from the 4th July to 11th November. Italian ryegrass with crimson and red clovers carried 8.8 sheep/acre for the same period.

(c) *Fertilizer Trials.*—A phalaris, red clover, and subterranean clover pasture treated with superphosphate annually at varying rates of from 0 to 2 cwt./acre has shown marked responses to the fertilizer, especially by the clover, which gave a fourfold increase in yield from applications of 2 cwt./acre compared with nil.

At Bundarra, the productivity of legumes was from ten to fourteen times greater with 2 cwt. superphosphate per acre than with no fertilizer and similar large differences were recorded at Glen Innes. Superphosphate also effected a high degree of weed control.

On a phalaris-white clover pasture on a basaltic clay soil which had previously received 2 cwt. superphosphate per acre for three consecutive years and had been heavily stocked, a further application of 2 cwt./acre in the fourth year resulted in an improvement in growth compared with the pasture which had received only 6 cwt.

Several experiments on the granite soils, commenced in 1950, gave strong evidence of plant nutrient deficiencies on these particular soils.

In an experiment reported previously the yield of clover in a sown pasture of phalaris, subterranean clover, and red clover was reduced from 26.8 to 16.7 cwt./acre when the soil pH was reduced from 6.1 to 5.3 with a sulphur application. It was found that at the lower soil pH applications of molybdenum resulted in an increase in the yield of clover from 12.0 cwt./acre without molybdenum to 21.1 cwt./acre with an application of 4 oz. sodium molybdate, made eighteen months previously.

(d) *Improvement of Natural Pastures.*—The second year's results of the experiments to test the effectiveness of different methods of sowing clovers into natural pasture showed a marked increase in yield of clover after sowing with a combine, compared with broadcast and disk-drill sowings. The use of superphosphate at 2 cwt./acre applied as a top-dressing in the autumn of the second year resulted in up to a tenfold increase in the yield of white and subterranean clovers in the early summer of the second year.

Pelleted subterranean clover seed used as an aid to clover establishment without ploughing, in dense native pasture, has proved to be no more effective than unpelleted seed. Likewise threshed subterranean clover seed gave better establishment than unthreshed seed when sown into dense native pasture.

(e) *Ecological Survey.*—A survey with the ultimate object of providing an assessment of the best potential land use of the New England region of New South

Wales has begun. The soils, natural vegetation, geology, physiography, and climate, and the interrelationships of each with the other, are being studied.

14. Pasture Investigations in Western Australia.

(*a*) *Grazing Management Trial.*—A trial was commenced in May, 1949, to determine the influence of grazing management on the botanical composition of a Wimmera rye sand brome grass (*Bromus arenarius*) subterranean clover pasture and on livestock production. It involves a comparison of continuous and autumn-deferred grazing with Merino wether sheep.

Following the excellent opening rains in early May, 1950, the sheep on the continuous treatment gained rapidly in body weight and by the third week in August had almost made up the initial lag from last year's differential grazing.

Body weights in the two treatments were practically equal until the end of January, 1951, when, as in the previous year, the "continuous" group declined faster than the "deferred".

Over the twelve-month period the sheep were maintained satisfactorily at a stocking rate of 2.67 sheep per acre on both treatments.

Under continuous grazing Wimmera ryegrass and capeweed became more prominent and the amount of *Bromus gussonii* decreased but the pastures under both systems of grazing remain subterranean clover dominant.

(*b*) *Species and Strain Investigations.*—(i) *Phalaris tuberosa.*—In 1949 this species was sown both in the autumn and in the spring at various row spacings to determine productivity and persistence at the Glen Lossie Field Station, Kojonup.

Results obtained so far indicate that the slight reduction in persistency with close spacing (7-in. rows) is more than compensated by the increased yield per acre obtained.

(ii) *Subterranean Clover.*—A large number of strains is being cultivated as single plants in spaced rows to enable those most suited to the environment to be selected for testing under sward conditions. In 1950 a sward trial of the most promising ones was established at Kojonup and it was of interest to note that although the performance during the first year was generally good, marked differences in re-establishment were evident the following autumn.

One of the most promising to date is the "early mid-season" strain from Victoria known as "Port Fairy".

(iii) *Cereals.*—Early wheats gave higher grain yields than mid-season varieties at Kojonup in 1950, the highest being Gabo, which produced almost 50 bus./acre. The most appropriate time of sowing is to be investigated during 1951.

Six varieties of oats, including three introductions, were used in a grazing trial and although winter production was fairly uniform, grain yields from the Ballidu and Algerian varieties were high.

(*c*) *Plant Nutrition Studies.*—(i) *Pot-culture Trials.*—Investigations on phosphorus toxicity in subterranean clover have been continued. The importance of nitrogen supply has been emphasized in one trial where heavy inoculation increased growth rate and alleviated the effects of high phosphorus. Both mono- and di-calcium phosphate caused toxicity at levels equivalent to 4 cwt. superphosphate per acre where nitrogen supply was very low; at intermediate levels, i.e. with normal inoculation, symptoms appeared only with the mono-salt; with high nitrogen, as $NaNO_3$, no symptoms were observed with either salt. Phosphorus toxicity has been developed in oats, also, where nitrogen and lime appear to have the same role as in clover.

(ii) *Field Trials.*—The effect of varying rates of potash fertilizer on the growth of three strains of subterranean clover is being examined at Perth. There is some indication that maximum yields are obtained with lower rates in Bacchus Marsh compared with the Dwalganup strain. At Kojonup both Dwalganup subterranean clover and capeweed responded to sulphur application. Further work on this deficiency will be conducted in the 1951 growing season. Pronounced residual effects on superphosphate occurred on Kojonup gravelly sand. The effects of varying rates on the yield and botanical composition of a clover pasture are still under examination. Only small responses to zinc occurred in the 1950 growing season on this soil type.

(*d*) *Pasture Investigations Relating to the Sheep Infertility Problem.*—Co-operative experiments, involving the bio-assay of subterranean clover by the Division of Animal Health and Production, were continued. Neither light intensity nor grazing intensity materially affected the potency of the clover grown at Kojonup during 1950. Moreover, it now seems certain that the decreased potency following high applications of superphosphate is due to phosphorus, as neither calcium nor sulphur was effective.

(*e*) *Grazing and Rotation Trial.*—This experiment, located at Wongan Hills, is a co-operative project with the State Department of Agriculture and the University of Western Australia.

Following the three-year pasture phase and the cropping of the whole experimental area to wheat in 1949, the second grazing cycle has been commenced. Despite some changes in the botanical composition of the several pasture types during the 1950 season, the general trends with respect to carrying capacity, sheep body weights, and wool production were in agreement with those obtained in the first grazing cycle. The cereal data showed that yields of both grain and hay following volunteer pasture were better than after oats for grazing and that a mixture of Wimmera rye and subterranean clover was more effective in building up soil fertility than volunteer pasture.

15. Pasture Investigations at Cunnamulla, Queensland.

(*a*) *Grazing Management Studies.*—An experiment comparing the effect of light, medium, and heavy rates of stocking of Mitchell grass pasture, under both continuous and rotational grazing, is now in its tenth year. Under the influence of four years with above-average rainfall, the feed supply of the experimental sheep has not been limiting, even under the heavy grazing treatment, and no difference in pasture yield or live weight and wool production of the sheep, due to grazing treatment, has been recorded. As a result of the abnormal seasonal conditions the pasture has become bluegrass (*Dichanthium sericeum*) dominant and the Mitchell grass has declined in vigour. This decline has been attributed to the direct effect of competition from the bluegrass because when this species was removed from experimental plots, the growth made by Mitchell grass in the 1950-51 summer was 2.34 g./10 sq.cm. of basal cover, whereas on plots from which the bluegrass had not been removed the comparable figure was 1.57 g./10 sq.cm.

(*b*) *Pasture Regeneration Studies.*—These are continuing although there have been no fresh developments since those recorded in last year's Report.

16. Pasture Investigations at Brisbane and Lawes, Queensland.

(*a*) *Natural Pastures.*—An experiment designed to give basic information on the natural spear grass (*Heteropogon contortus*) pastures at Calliope near Gladstone commenced in January, 1947, and was completed in January, 1951. Botanical analyses of the

forage have shown that *Heteropogon contortus* constitutes from 70 to 90 per cent. of the dry matter yield. Highest yields recorded were—

	Cwt./acre.
Spear grass	20
Other grasses	2
Miscellaneous species	1.8
Legumes	0.3

In each year the greatest bulk of feed was produced following the incidence of effective rainfall between January and April, although early rainfall gave a fair growth between October and January. Even with adequate rainfall, there was virtually no growth in the winter months.

Chemical analyses show that this spear grass is deficient in protein and in phosphorus for a considerable part of the year and that pasture legumes are needed to improve the quality of the herbage.

It has been shown that the carrying capacity of these native spear grass pastures can be considerably improved by introduction of Townsville lucerne (*Stylosanthes sundaica*), Stylo (*Stylosanthes gracilis*), and *Phaseolus lathyroides*, and that such improved pastures respond quite well to superphosphate. The introduction of these grazing legumes can be readily achieved at no great cost by surface sowing without destroying the natural grass sward.

(*b*) *Introduced Pastures.*—The most promising grasses to date are Rhodes (*Chloris gayana*) and scrobic (*Paspalum scrobiculatum*), and various trials are in progress to determine the most effective cultural treatments for obtaining maximum production from these grasses and suitable associated legumes.

(i) *Row-cultivated Pastures.*—During the past two years, experiments with sown pastures have yielded some conclusive data on the hitherto elusive comparison between rows and swards. Previous experiments were complicated by the effects of preferential grazing. In one case, pastures of *Paspalum scrobiculatum* were grown on black soil and grazed only during the winter months; swards gave the lowest production. Relative yields were—

Spacing.	Dry Matter (cwt./acre) (mean of four pastures).	Nitrogen (cwt./acre) (mean for two pastures).	Rows per Unit Area.
Swards	57	69	515
3-ft. rows	100	100	100
4-ft. rows	78	72.5	75
5-ft. rows	68	60	60

With row cultivation, yields were in proportion to the number of rows per unit area, but the yield from swards bore no relation to what was essentially a greatly increased number of rows. Under practical conditions, it has been found that 36-in. spacing is unsuitable for cultivation with large implements and spacing of 42 in. has been adopted. The yield of weeds was highest in swards and the percentage weed growth was greatly reduced by row cultivation.

In lucerne pastures, mean annual yields from swards and from rows at 42-in. and 63-in. spacing all tended to a common level, since the yield per unit row length decreased in proportion to the number of rows per acre. In a sward, the greatest bulk of dry matter was produced in relatively short wet periods immediately after effective rainfall. In rows, active growth extended over a much longer period of time. The difference in behaviour, as between pastures of lucerne and of *Paspalum scrobiculatum*, has been related to corresponding differences in the supply of available soil moisture.

In another experiment pastures of *P. scrobiculatum* were subjected to year-long grazing, but the spacing treatments were separately fenced. It was found that under the same intensity of grazing initial differences in yield, as between rows and swards, tended to disappear in the second and third years, and that there was some improvement in the yield and vigour of plants in a sward. It follows that the marked increase in yield hitherto recorded under row cultivations occurs only under conditions where some essential requirement (e.g. water or plant nutrients) is in short supply.

Over all spacing treatments, the total yield of dry matter from mixed pastures of *P. scrobiculatum* and lucerne (whether planted in alternate rows or as a trne mixture in swards and in rows) was appreciably less than that from a pure stand of the grass. The total yield from mixed pastures of *P. scrobiculatum* and the annual legume, *Phaseolus lathyroides*, greatly exceeded that from a pure stand of grass.

(ii) *Rhodes Grass.*—A grazing trial to compare two strains of Rhodes grass alone and in association with lucerne is continuing. Whilst the grazing on Rhodes grass pastures is considerably better than oa natural grassland, a further marked improvement cau be achieved by the introduction of a small quantity of lucerne. This can be readily established in old stands of Rhodes grass with late summer seeding, but attempts to introduce this legume into young grass stands in the springtime have not so far been successful.

(*c*) *Grazing Management.*—Experiments so far indicate that the basic pastures should be: (i) alternate rows of scrobic and *Phaseolus lathyroides*, and (ii) lucerne, with areas of special pasturage consisting of scrobic and lucerne for lambing ewes and dry sheep and Rhodes and lucerne for cattle.

Various trials are in progress to determine how these better pasture species should be grazed in order to get maximum carrying capacity.

Rows of scrobic are being subjected to various rates of defoliation to determine its resistance to heavy grazing and its ability to produce herbage under such treatments.

Although a mixed pasture of Rhodes grass and lucerne provides good feed in summer, it has limited value in winter. On the other hand, lucerne provides good winter feed under Queensland conditions.

In order to gain information on alternative grazing of these two types of pasturage an experiment is in progress to measure growth and production in beef cattle under two grazing managements, viz., continuous grazing on Rhodes/lucerne mixture, and Rhodes/lucerne for summer and lucerne only during the winter.

(*d*) *Soil Fertility Studies.*—Oats and sorghums grown on areas that have been under improved pasture show increased yields due to the build-up of soil fertility that has occurred, indicating further benefits in addition to the increased carrying capacity.

The ability of various types of pasturage to build up soil fertility is being assessed in terms of crop yields and by appropriate chemical and physical tests.

(*e*) *Plant Nutrition Studies.*—Work on the Darling Downs heavy clay soil has been continued with good effects on plant growth from heavy applications of ammonium sulphate and from soil sterilization by steam. Smaller and more variable effects have followed the use of minor elements, especially manganese and zinc. By using different species as test plants and a new experimental design, it has been shown that sulphur has an important role in relation to plant growth.

Plant nutrition studies using soils from Rosewood, Clifton, Elimbah, and Redland Bay are in progress. Soil-plant cation relationships and water culture investigations have been initiated, but the work has not progressed beyond the development of satisfactory techniqnes and procedures.

(*f*) *Pasture Chemistry—Evaluation of Pasture Species.*—An estimate of potential food value of pasture plants has been attempted on the basis of chemical analyses. It is hoped that this work will place the selection of species on a much sounder basis.

In a preliminary survey, a direct comparison between 29 grasses was made by recording the number of harvests yielding approximately 100 lb. of digestible protein per acre, with a ratio of digestible starch equivalent/digestible protein better than 10:1. It was found that relatively few species, notably *Phalaris tuberosa, Paspalum notatum,* and *Paspalum setaceum,* would pass this test.

The validity of this method for evaluating introduced plants is at present being tested by application of the technique to grazing trials, wherein the live-weight increments of animals are recorded. The possible effect of climatic and soil factors is being studied by growing a limited number of species on other soil types and in different climates.

17. Pasture Investigations at Ayr, Queensland.

The Land Research and Regional Survey Section is co-operating with the Queensland Department of Agriculture and Stock in investigations of tropical pasture mixtures under irrigation in the Burdekin Valley. These investigations include preliminary trials of pasture grasses and legumes, including selections from species not in commercial use as well as some established species, and a beef cattle grazing experiment with five grass-legume mixtures.

Of the species under preliminary examination *Paspalum scrobiculatum, Panicum maximum, Melinis minutiflora,* and *Panicum* spp. aff. *coloratum* have shown themselves worthy of further investigation. The legumes *Pueraria phaseoloides* and *Glycine javanica* have become well established and deserve further trial. *Medicago sativa* does not do as well as the other two legumes. All species which have been grazed periodically have proved relatively palatable except *Glycine javanica.*

The five pasture mixtures included in the grazing experiment described in the last Annual Report have now been thoroughly established and given preliminary grazings. Regular pasture sampling and experimental grazings, which will yield annual live-weight increases, for each pasture mixture are to be commenced in July.

Preparations are being made for the commencement of an experiment designed to compare the growth habits of a wide range of introduced pasture grasses under various treatments involving different periods and frequencies of cutting.

18. Weeds Investigations and Plant Toxicology Studies.

(*a*) *Effects of Plant Growth-regulating Substances on Perennial Weeds.*—Results obtained in previous years indicated that plant growth-regulating substances showed little promise of control of skeleton weed (*Chondrilla juncea*). In order to ensure that no possibilities of control by this means had been overlooked, one trial has been carried into the third year. It involves nine formulations at four concentrations, applied at various growth stages and frequencies. Only temporary control is obtained by any of the treatments. It appears that there is no prospect of control of established skeleton weed by this means alone in the Cowra district. The experiment is to be discontinued following a count in spring.

The esters of 2,4,5-T and mixtures of esters of 2,4-D and 2,4,5-T were further tested on blackberry (*Rubus fruticosus*). Concentrations of 0.1, 0.15, and 0.2 per cent. were sprayed at 200 gal./acre. No regrowth had appeared five months after spraying on any of the treatments. It is interesting to note, however, that in another experiment spraying with the highest concentration (0.2 per cent.) in March was followed by some regrowth. The lower concentrations gave complete control and no regrowth was found twelve months after spraying.

Similar experiments on sweet briar (*Rosa rubiginosa*) using 100 gal./acre at strengths from 0.1 to 0.2 per cent. gave 2 to 5 per cent. regrowth from below gronnd level. The plots were resprayed four months after the original treatment, using half the quantity of spray. The results of the respraying cannot be assessed until next spring.

(*b*) *Control of Perennial Grass Weeds.*—At Griffith, New South Wales, investigations of the herbicidal properties of oils have been continued. In addition, chemical separation of oils was undertaken to provide information not otherwise available on the chemical composition of oils. These oils were tested in the glasshouse and the importance of the boiling point of the oil *per se* in toxicity has been established.

Oil emulsions fortified with sodium pentachlorphenate (PCP) have been tested for use in various situations. Further work is necessary but this type of herbicide is promising as a contact herbicide for use in the control programme for cumbungi (*Typha* sp.) and for non-cultivated orchards where straight oil would normally be used.

Following the promising results obtained with the salts of trichloracetic acid (TCA) on Johnson grass reported earlier, more detailed trials of these compounds were undertaken. Trials were applied to Johnson grass (*Sorghum halepense*), common reed (*Phragmites communis*), and other grass weeds. Unfortunately results obtained have been extremely variable and rainfall and irrigation appear to influence the degree of control obtained. Paspalum (*Paspalum dilatatum*) and some annual grasses are extremely resistant to TCA. Further work with this promising group of herbicides is proposed.

(*c*) *Mintweed Control.*—Investigations have been continued mainly with a view to determining the factors responsible for the success of the weed in competition with economic plants. Depth of sowing has a marked effect on the germination of mintweed, the deeper the sowing the less the germination. This suggests that control of this weed would depend largely on preventing germination of surface-borne seed.

A pot trial has shown that mintweed germinates more rapidly than any of the selected grass species. Pre-emergence spraying with "Methoxone" prevented germination of both mintweed and the crop species tested.

It was previously found under field conditions that spray applications of ammonium bisulphate stimulated the growth of competing grass species, inhibited the germination of mintweed seed, and killed established mintweed plants. This observation has been followed with a pot experiment in which mintweed was grown in competition with selected grasses in the presence of certain sulphates. It was found that pre-sowing treatments had little effect on mintweed germination, that sulphuric acid had little effect on yield of mintweed or grass, and that ammonium sulphate significantly increased the yield of grass but not that of mintweed. The response to ammonium sulphate was significantly greater with Rhodes grass (*Chloris gayana*) than with bluegrass (*Dichanthium sericeum*) and in general the yield of mintweed in competition with Rhodes grass was less than in competition with bluegrass. These observations, in association with results from plant nutrition studies on the black soils, suggest that given adequate supplies of available nitrogen and sulphur, sown pastures would compete effectively with mintweed.

The possibilities of effective mintweed control by competition with native pasture plants are being studied, particular attention being given to the collection, dispersal, and germination of the seed.

(*d*) *Timber Regrowth Control.*—A series of experiments on factors affecting the germination of *Eucalyptus tereticornis* has been delayed pending collection of appropriate seed samples. Studies have been continued on the effectiveness of phenoxyacetates applied to frilled trees or cut stumps. No clear differences between 2,4-D and 2,4,5-T at equivalent concentrations have been observed. With 2,4,5-T the ethyl ester was no more effective than the sodium salt.

(*e*) *Mistletoe Investigations.*—Collaborative investigations with the Commonwealth Forestry and Timber Bureau have been continued. Good results have been obtained in the control of *Loranthus pendulus* by injecting 2,4-D into the host trunks. The results with 2,4,5-T have been fair, the results with other poisons poor. The optimal dose of 2,4-D varies with season, and possibly with host species and locality. An offer made by the Queensland Main Roads Commission to test the 2,4-D treatment in Queensland has been accepted.

(*f*) *Electrical Diagnosis.*—Further measurements on potato tubers with and without virus X have confirmed an earlier conclusion that it is possible to distinguish between healthy and diseased batches on the basis of phase-angle measurements, and have shown that it is possible to discriminate between batches on the basis of impedance measurements. It seems likely that discrimination can be made between healthy and Y-infected batches on the basis of phase angle.

A wide-range sine-wave oscillator has been constructed for further investigations.

(*g*) *Tracer Investigations.*—In order to follow the movement of applied poisons, a chemical separation for As^{75}, P^{32}, and S^{35} is being investigated, and a number of difficulties have been overcome.

(*h*) *New Poisons.*—Arrangements have been made for collaborative work with the University of Technology, whereby the University synthesizes new compounds so that working hypotheses concerning toxicity can be checked. A number of new poisons are under test.

(*i*) *Modification by 2,4-D.*—Applications of 2,4-D to *Paspalum dilatatum* decrease its yield of dry matter but increase its percentage protein content. This observation may be of value in paspalum districts where low protein content of pastures limits milk production.

19. Katherine Research Station.

Previously known as the Katherine Experiment Station, the name of this Station has recently been altered to the Katherine Research Station.

The main investigations by the Land Research and Regional Survey Section at this Station are being carried out on the limestone red soils of the Tipperary land system in an endeavour to determine the possibilities of agricultural development under dryland conditions. Additional work is being conducted on the river levee soils where water is available for the irrigation of intensively grown crops.

(*a*) *Soil Fertility Problems on the Limestone Red Soils.*—(i) *Fertilizer Requirements.*—The fertilizer requirements of these soils have been examined in replicated fertilizer trials with a variety of crops. There is evidence to suggest that the requirements in the first year of cultivation are higher than those in subsequent years or alternatively that there is marked residual effect of fertilizer and cultivation. The virgin soil requires up to 3 cwt. of superphosphate per acre to satisfy the main crops. Non-leguminous crops also require up to 2 cwt. of sulphate of ammonia in order to produce maximum yields. Initially an annual dressing of 1½ to 2 cwt. of superphosphate per acre for all land under cultivation or improved pastures appears to be the basis of soil fertility maintenance. Potash treatments have been included in all fertilizer trials but as yet no response to potash has been observed.

(ii) *Continuous Cropping.*—The effect of continuous cropping of these soils with both cotton and peanuts is being investigated. Results so far indicate increased cotton yields in the second year in each of three fertilizer treatments (nil, superphosphate, and superphosphate + potash). The proportional increase in the fertilized plots is slightly greater than in the unfertilized plots. With peanuts there has been a marked decrease in yield in the second year, due mainly to an increase in the incidence of a crown rot disease, which substantially reduced the plant stand. It appears that unless control measures can be devised peanuts should not be cropped on the same land successively.

(iii) *Special Soil Investigations.*—The limestone red soil has an acid reaction. Peanuts, especially the variety Virginia Bunch, have a special need for readily available calcium at the fruit setting stage to avoid ovule abortion. An experiment with two varieties of peanuts as the indicator plants shows that there is no advantage from additions of lime. The effect of top-dressing with gypsum has also been examined with negative results. Preliminary experiments have shown no response to the addition of the commonly deficient minor elements.

(*b*) *Crops.*—Further crops of cotton, grain sorghum, and peanuts have been produced on the limestone red soil. The yield of seed cotton for the 1949-50 season was 500-600 lb./acre, varying according to fertilizer treatment. Many introduced varieties have now been examined, but none has equalled the Queensland strains of the Miller variety. The yield of grain sorghum in the 1949-50 season was 30 bus./acre in the best fertilizer treatments. Hegari strains are consistently the highest yielding, but are rather tall and have soft grain. Several double dwarf varieties of lower height and with harder grain and good yield show promise. An extreme dwarf type of Hegari selected at Katherine has outyielded Kalo and may be of considerable value under lower rainfall conditions for fodder purposes. Peanut yields for the 1949-50 season were high, exceeding 2,000 lb./acre for the best treatments. Yields for the 1950-51 season appear to be a good deal less owing to the very wet conditions and the greater incidence of crown rot. The best treatment yielded about 1,000 lb./acre. Numerous introduced varieties have been examined, but none has outyielded local varieties. Shelling percentages for different varieties have varied from 60 to 90 per cent.

Of the three main crops, peanuts are outstanding because of their adaption to the hot climatic conditions and the short growing season, and because of their phosphate thrift. Grain sorghums are only fairly well adapted to the climatic conditions and not at all to the low phosphate content of the unfertilized soil. Cotton is reasonably well adapted to the wet summer conditions, and the dry autumn is favorable for maturation and harvesting. This crop requires a high phosphate level and is somewhat limited by the length of the growing season.

The agronomic research at Katherine is carried on in very close co-operation with the Plant Introduction Section of the Division of Plant Industry. Introduced crops which have been demonstrated by this Section to have promise for dryland agriculture in the region

are placed in larger trials on the dryland farm. Amongst those crops for which plans are being made for more extensive experiments are sunflower (*Helianthus annuus*) for oil, Roselle fibre (*Hibiscus sabdariffa*), and *Phaseolus aureus* as a high-protein pulse crop.

(*c*) *Mixed Cropping.*—A preliminary experiment has been conducted to examine the production of grain sorghum and peanuts when sown alone and when sown in alternate rows. Where additional phosphate was applied, the grain sorghum produced approximately as much grain from a much reduced total bulk of plant material when sown in competition with interspaced rows of peanuts as when sown alone. The physiological reason for this increased efficiency of grain production in the mixed plots is to be investigated.

(*d*) *Pasture Investigations.*—Pasture investigations have been continued along two lines, the investigation of species and mixtures for sowing on cultivated land and the improvement of native pastures by the introduction of legumes. The long dry winter has proved to be a critical factor in determining the suitability of grass species for cultivated land. Observation plots of various mixtures have indicated that Guinea grass (*Panicum maximum*) and Rhodes grass (*Chloris gayana*) fail in this respect. Four grasses, of very different habits of growth, *Andropogon gayanus, Urochloa bulbodes, Cenchrus* sp., and *Digitaria* sp. have survived satisfactorily. All pasture mixtures sown have included Townsville lucerne (*Stylosanthes sundaica*), Stylo (*Stylosanthes gracilis*), or *Clitoria ternatea*. The last species appears to require better moisture conditions. Of the two *Stylosanthes*, the annual species *S. sundaica* has shown the greater promise. It shows greater phosphate thrift and on unfertilized land is able to compete satisfactorily with the introduced grasses.

The improvement of native pastures has been concerned mainly with the introduction of Townsville lucerne. It has been shown that this legume can be established in grazed native pastures without application of superphosphate or surface cultivation, but it responds to both treatments by better establishment, greater bulk, and greater seed production. This effect is carried over into the second year. The germination and establishment of Townsville lucerne seed have been improved considerably by dehulling.

(*e*) *Pests and Diseases.*—Most of the crops grown at the Station have been cultivated for five years and several of the main crops have been cultivated or have survived in the wild state for much longer. In spite of this and the presence of indigenous members of these genera in the area, there has been general freedom from pests and diseases. Bird damage to grain in small or isolated plots of grain sorghum is serious. Peanuts are attacked by a crown rot disease which can cause a serious depletion of the stand. Pink and rough boll worms are serious on cotton early in the season, but seem to disappear completely later on. Grasshoppers have not yet caused any damage at Katherine, although large swarms of hoppers are common early in the season.

The investigations on the levee soils have mainly concerned tobacco and new plant introductions. The results are reported elsewhere.

20. Kimberley Research Station.

The investigations of agronomic and pasture problems under irrigation at the Kimberley Research Station, conducted by the Land Research and Regional Survey Section, are being continued in co-operation with the Western Australian Department of Agriculture. Apart from their significance to plans relating to the development of this region, the investigations at the Kimberley Research Station have application to other heavy soil flood-plain regions of northern Australia. In view of the progress made in the initial experiments a research officer has been appointed to the station.

(*a*) *Soil Fertility Problems.*—Further experiments have confirmed the need for phosphate applications for adequate production of all crops and pastures, and that moderate to heavy nitrogenous fertilizer applications are necessary for crops such as rice and sugar cane. The need for potash application has not been so well defined and indications of phosphate-potash and nitrogen-potash interactions require further investigation. The role of sulphur in relation to soil fertility is being studied and preparations are being made for a series of pot experiments to supplement the field work. There have been no significant responses to minor elements with either gramineous or leguminous species.

The extent to which nutrient deficiency may be contributing to the decline in productivity of pasture grasses in the second and third years after establishment is receiving attention.

(*b*) *Pasture Investigations.*—Pastures based on Rhodes grass (*Chloris gayana*), *Paspalum dilatatum*, Para grass (*Brachiaria mutica*), Guinea grass (*Panicum maximum*), and buffel grass (*Cenchrus ciliaris*) have now been observed over a period of several years. All pastures are still showing a marked decline in productivity, and this problem is being investigated. The establishment of a pasture legume alone, with the object of building up fertility before introduction of the desired grass species, is now being examined. An area of the legume *Clitoria ternatea*, which has shown consistently good growth and resistance to locusts, is being planted this dry season and will later be grazed before over-sowing with grasses. Field confirmation is required of the results of a recent pen feeding test in which a steer was fed exclusively on freshly cut material of this plant for a period of one month without any apparent toxic effects.

New pastures are also being established. These include the grasses *Paspalum scrobiculatum*, Guinea grass (*Panicum maximum*), Para grass (*Brachiaria mutica*), *Andropogon gayanus*, and *Cenchrus ciliaris* Type B, each in association with the two most promising legumes, *Stylosanthes gracilis* and *Clitoria ternatea*. Difficulty has been experienced in building up adequate seed supplies of some of these introductions. It appears that establishment from seed is less satisfactory during the wet season than during the cooler dry season when seed-bed conditions can be better controlled under irrigation.

Pastures of Rhodes grass alone and Rhodes-legume mixtures have been grazed by beef cattle. Observations so far indicate that the pastures could not be satisfactorily grazed in the wet season on these heavy soils. Areas have been inadequate for a fully controlled grazing trial, but the best live-weight increases have been on the Rhodes-legume mixture. The improvement in the condition of the animals after only a short period on this irrigated pasture mixture after coming off a deteriorating native pasture, early in the dry season, has been promising. Live-weight gains on Rhodes-legume pastures have been of the order of 2 lb./day and up to 3 lb./day for short periods. These compare with gains of ¾ lb./day on native pastures.

Among the newer introductions of pasture species strains of the grasses *Setaria sphacelata, Panicum* sp. aff. *coloratum, Digitaria* sp., and *Paspalum simplex* appear most worthy of more extensive trial. Several strains of peanuts show promise as pasture legumes. Other legumes of possible pasture or green manure

value are under observation. Further experiments are being conducted with lucerne, which has not been successful on the clay soil in the past. Sudan grass, bulrush millet, and elephant grass are being compared for fodder production.

(*c*) *Crop Evalution and Variety Comparison.*—Peanuts have continued to give commercially satisfactory total yields in small plots, of the order of 2,000-3,000 lb./acre, but the shelling percentage has been disappointing. A few of the introduced varieties appear promising and yield comparisons between them and the standard varieties Virginia Bunch and Red Spanish are to be made. Yields of 40 to 70 bus./acre of grain sorghum have been produced according to the season. The highest yields have been obtained with local selections from the variety Caprock. Variety selection work is being continued. A wide range of cotton varieties are under observation. A good crop of cotton, variety Locket 140, was grown during the wet season 1950-51 but the potential yield of lint was greatly reduced by pest damage and the final yield was 461 lb. seedcotton/acre. Alternative Malvaceous host plants are numerous in the area. A strict pest control régime appears necessary to obtain satisfactory commercial yields.

Small samples of tropical varieties of rice, of which 25 were from New Guinea, have been grown during the 1950-51 wet season. These included the most promising varieties yet grown on the station. The variety CPI 12902 "Radin Siak" from New Guinea is the latest maturing and most attractive of all. Sufficient seed has been harvested for more extensive trial of the leading varieties.

Twelve varieties of sugar cane, including the leading irrigated canes of the Burdekin region, have made very satisfactory growth in small observation plots. The multiplied material is to be used this season for planting a replicated fertilizer and varietal yield trial.

Linseed appears well adapted to growth during the cooler months of the dry season. There is an indication that early maturing varieties will be the most satisfactory. A wider range of varieties is being planted this season. Several varieties of safflower will be under observation in nursery rows during the current season. A wet-season sunflower crop gave a commercially satisfactory yield but matured during the wet period and would have been too early for mechanical harvesting.

(*d*) *Irrigation.*—A frequency of irrigation experiment with a Rhodes grass pasture indicates that the most satisfactory watering interval during the dry season is approximately four weeks. Furrow irrigation with run lengths of up to nine chains has proved satisfactory and is being used for most crops. For adequate lateral seepage well-prepared ground and a broad-based furrow are necessary on the Cununurra clay soil. The border-check method is used for pastures and closely spaced crops such as linseed. Approximately eight acre feet of irrigation water was necessary for the last wet-season rice crop in addition to 22 inches of rain received during the growing period.

(*e*) *Pests and Diseases.*—Grasshoppers, principally the yellow-winged *Gastrimargus musicus,* were again troublesome during the wet season, attacking mainly gramineous species. A number of otherwise promising grasses and the legumes Stylo and *Clitoria* were relatively immune. Control measures possible with the limited staff of an isolated station are impracticable once the winged stage is reached. Little corellas and finches have again caused damage to earing sorghum, rice, and grasses. Of the numerous cotton pests the pink boll worm, *Platyedra gossypiella,* has been the most important. There was an increase in the incidence of a crown rot disease of peanuts during the last wet season.

21. Regional Surveys.

In addition to agricultural research at field stations in northern Australia, the Land Research and Regional Survey Section conducts resources surveys of large under-developed regions in Australia, Papua, and New Guinea in collaboration with other Divisions and Commonwealth Departments.

(*a*) *Townsville-Bowen Region.*—During September and October, 1950, a survey was made of the Townsville-Bowen region, which covers an area of 6,400 square miles, including the Lower Burdekin River Valley. A preliminary report on this region, including special consideration of the irrigation proposal in the Burdekin Valley, was presented in December, 1950. A map, indicating a subdivision of the lands of the region into seven land-use groups, accompanied this report. A more comprehesive report has been prepared, including a map of the 19 land systems of the region, which have been described in detail. Both maps have been produced on a scale of 4 miles to 1 inch.

(*b*) *Barkly Region.*—Coloured maps showing the geomorphological units and the land systems of this region have been printed and are available for distribution. These maps, which are produced on a scale of 16 miles to 1 inch, cover an area of approximately 120,000 square miles.

(*c*) *Ord-Victoria River Region.*—Preliminary work on the data collected in the 1949 field season has been commenced. It is planned to complete the field work of this region in 1952.

(*d*) *Papua-New Guinea Resources Survey.*—A long-term resources survey of all these Territories is to be conducted at the request of the Department of Territories. Preliminary steps have been taken to organize a new unit for this purpose.

22. Mineral Nutrition of Plants in the Coonalpyn Downs, South Australia.

The investigations of the mineral nutrition of plants grown in the soils of the Coonalpyn Downs, South Australia, have been continued by the Division of Biochemistry and General Nutrition. Following a recent decision of the State Nomenclature Committee the name Coonalpyn Downs has been officially adopted for the region previously known and referred to as the Ninety-mile Desert. The implications of this are obvious.

The initial experiments on the Coonalpyn Downs were carried out on a soil type known as Laffer sand, which consists of approximately 15 inches of grey siliceous sand resting on about 6 inches of sandy clay over limestone. The results of these have been recorded in earlier reports and in various publications, which have provided the basis for the development of this refractory area.

Detailed investigations are now being carried out on Buckingham sand, which is a much heavier soil, and on two soils lighter than Laffer sand; one of the latter is near Coombe and the other near Tintinara. The fact that these soils are limited by deficiencies of both zinc and copper has been established by experiments. The severity of these deficiencies varies in degree. It is acute in the lightest soils, and is incipient but nevertheless economically important in the heavier soils such as those known as Buckingham sand. Each of these soil types has been found to present a number of additional problems peculiar to itself, and these are regarded as facets of the overall problem of pasture establishment and maintenance on this large tract of

deficient terrain. A number of long-term experiments has recently been completed and the results are being prepared for publication.

(*a*) *Experiments on Buckingham Sand.*—There are extensive areas of Buckingham sand east of Keith awaiting development. The soil there consists of three inches or so of siliceous sand over clay which extends 60 feet or more in depth. The natural vegetation is an association known as mallee-broombush in which *Eucalyptus incrassata* and *Melaleuca uncinata* predominate. Subterranean clover was found to grow extremely well on this soil, provided the incipient deficiencies were corrected by an addition of zinc and copper at seeding. Superphosphate applied in amounts up to 6 cwt./acre at seeding had no detrimental effect on yield of herbage, and had a markedly beneficial residual effect on the two succeeding years. Highly satisfactory growth of the clover was obtained by annual applications of 1½ cwt. of superphosphate per acre. Serpentine superphosphate was no more effective than ordinary superphosphate. Of five varieties of subterranean clover tested, Bacchus Marsh and Mount Barker proved most productive on these soils. An application of 7 lb. each of zinc sulphate and copper sulphate per acre has been recommended to correct the deficiencies on new land in the Coonalpyn Downs. Investigations are being made to determine whether this amount can be safely reduced in areas where the deficiencies are merely incipient.

So far, no visible sign of deficiency other than those of phosphorus, nitrogen, zinc, and copper has been detected in plants grown in Buckingham sand, and no consistent responses have been observed to supervene on the application of other nutrient elements. The possibility that other deficiencies may develop as the pastures age is not being overlooked.

In preliminary trials of a number of pasture species, on new land, perennial ryegrass was found to grow well in association with subterranean clover. Phalaris under the same conditions virtually failed on account of nitrogen deficiency, but developed well when sown into ploughed, three-year-old clover pasture.

Lucerne does not thrive in grazed pastures grown on Buckingham sand, and in closed experimental areas the yields of lucerne were less than half those of subterranean clover grown under identical conditions. At this site the growth of lucerne was not improved by the addition of copper and liberal dressings of superphosphate. The plants grow slowly to a height of 6 to 9 inches. The leaves are then shed, usually before the flowering stage is reached, and the stems wither and die. Fresh growth starts from the base of the plants. The cause of this abnormal behaviour is still obscure. Preliminary chemical examination of leaf samples has not revealed any obvious evidence either of deficiency or of toxicity. Field plots have been established to determine the effect of the addition of several nutrients and of other materials, and a study of root distribution of the plants is to be made.

Cereal crops grow poorly on recently cleared Buckingham sand. This was found to be due to nitrogen deficiency. Dressings of less than about 2 cwt. of soluble nitrogenous fertilizer per acre, however, were not markedly beneficial, and the use of the heavier dressings that are necessary to promote vigorous growth would not be economically feasible. Satisfactory yields of wheat were obtained on ploughed land that had carried subterranean clover for three years.

The economic advantages of growing cereals as a nurse crop when establishing young pastures on new land or as a preliminary crop have been referred to in previous reports. In areas, such as the Buckingham sands, where this procedure fails, a logical alternative is to grow one of the large-seeded legumes. Preliminary tests with a few species of these legumes gave very promising results in 1949 and a further more extensive test has since been carried out. Over 100 different species and strains of *Pisum, Vicia, Lupinus,* and *Lathyrus,* obtained mostly from the Division of Plant Industry and the Western Australian Department of Agriculture, have been grown for the purpose of a preliminary test of performance and for multiplying the very small quantities of seed that were available. Further testing and multiplication of 40 of the most promising of these is in progress. In the determination of suitable species the criteria include factors such as productivity, habit of growth, time of maturity, resistance to attacks of insect pests, such as the red-legged earth mite and the pea grub, ability not to shed grain, high germination capacity, &c. Studies of the performance and of the nutritional requirements of subterranean clover grown either in association with or subsequent to crops of this nature await the selection of species suitable for this area. In preliminary tests, field peas have shown most promise in respect to grain production, and the Dun variety has proved superior to Brunswick or Collegian. The use of peas as a crop on new land of this nature is, however, attended by certain disadvantages.

(*b*) *Experiments near Coombe.*—The soil at this site consists of siliceous sand which extends to depths exceeding 6 feet, three ½-in. thick bands of clayey sand, 4–5 inches apart, occurring in the profile about 2 feet from the surface. The natural vegetation is a low heath. Attempts to grow subterranean clover in this soil failed completely because of an acute deficiency of both zinc and copper. The young plants developed severe symptoms of zinc deficiency soon after germination, and ceased to grow, but developed normally and grew well if zinc and copper were applied. Dressings of superphosphate in excess of 1½ cwt./acre were observed to accentuate the symptoms of zinc-deficient plants. Application of the equivalent of 7 lb. of zinc sulphate and copper sulphate per acre corrected the deficiencies and enabled subterranean clover to be grown successfully. The effect of heavier and lighter dressings than these is being investigated in order to determine the range between the minimum effective concentration and the toxic levels of zinc and copper. Subterranean clover grown in this soil has revealed no signs of deficiencies other than those of phosphorus, zinc, and copper, which may be corrected by the application of manurial dressings containing these elements. Under certain conditions, however, abnormal growth of young clover plants has been observed in this area. The reason for this is being investigated by the Microbiology Section of the Division of Plant Industry, and is discussed in Section 4.

The growth and performance of five varieties of subterranean clover have been tested, and of these the Bacchus Marsh and Mount Barker strains have proved best suited to the conditions. According to the information which these tests have provided, the Bacchus Marsh variety, which flowers 8–12 days earlier than the Mount Barker variety, is preferable. *Trifolium hirtum*, introduced from the United States, showed promise as an alternative to subterranean clover. On areas where copper sulphate had been applied, lucerne became successfully established in this soil, and, under these conditions, an initial dressing of 4½ cwt. of superphosphate per acre ensured a maximum yield. The residual effect of this heavy dressing of fertilizer was considerable. Cereals grow reasonably well in this soil for the first year or two after clearing, but under many circumstances a preliminary establishment of a legume crop is a more economic procedure. Satisfactory yields of grain and of herbage have been obtained from several large-seeded legumes grown in preliminary tests on this soil. Of the three varieties of field peas tested, the highest yield was obtained from the Dun variety.

(*c*) *Experiments near Tintinara.*—The soil at this site consists of siliceous sand which exceeds six feet in depth, and which drains very rapidly. The indigenous vegetation is heath with occasional trees of stringybark (*Eucalyptus baxteri*). Application of copper to lucerne at seeding was found to bring about a marked increase in yield in the second and third years, though not in the first year. An annual dressing of 1½ cwt. of superphosphate per acre to lucerne which had been sown on areas treated with copper appears to be the economic limit at this site, probably because of the absence of a moisture-retaining subsoil.

(*d*) *General.*—Symptoms of zinc deficiency and copper deficiency produced in subterranean clover grown in deficient nutrient solutions closely resembled those observed in plants grown in the deficient soils. It should be realized, however, that recognition of these symptoms in plants growing under natural conditions is an aid to diagnosis only when prevailing deficiencies are acute. Frequently a state of deficiency is encountered in the field which imposes serious limitations to the growth of plants without revealing any obvious symptoms. Lucerne, for instance, even in a state of relatively acute copper deficiency, may exhibit no symptoms other than a marked reduction of yield. As a further aid to diagnosis some knowledge of the range and critical values for zinc and copper content of the plants is being sought. Plant material (leaf and petiole) has been collected for analysis as it has become available in controlled experiments on the different soils.

IV. IRRIGATION.

1. General.

The main establishments of the Organization for research in connexion with irrigation are the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales. The work of these stations is reported in this Chapter. Much of it is closely related to the problems of the regions in which they are situated.

Irrigation studies have been made also at Deniliquin, New South Wales, Ayr, Queensland, and the Kimberley Research Station, Western Australia.

2. Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria.

The Merbein Station has always maintained strong interest in the problems of the dried vine fruits industry, and the location of the Station on an area of saline land in the Mildura district has led naturally to continued detailed investigation of irrigation practice and of drainage and reclamation processes. The Station's work extends over the middle and lower Murray areas and covers a broad field of investigation necessitated by the wide range of crops and environments represented in these irrigation areas.

(*a*) *Irrigation, Soil Preservation, and Reclamation.*—The principles and practice of application of irrigation water to the surface of the land by means of furrow and flood irrigation are now well understood. Spray irrigation has been used for a long time, but recent years have seen greatly increased interest in this practice throughout the world. Much investigation remains to be done before the most satisfactory system to suit particular conditions can be defined. Equipping of a test area for spray irrigation at the Station has been completed. Among other things, distribution of water from various kinds of spray nozzle will be investigated, and the drop sizes of water sprayed under various conditions will be determined. Further work has been done on the measurement of flow of irrigation and drainage water. The Organization's Central Experimental Workshops modified the design of a rotor water meter developed at the Station, and constructed a 9-in. rotor to run inside a 12-in. pipe with shaped entry and exit for water. The shaping was such that casting in concrete, using forms produced under workshop conditions, would be practicable. Tests on a modified meter carried out at Melbourne Technical College indicated that, although the overall loss of head at a flow of 3 cusecs was less than 3 inches, the meter was not sensitive at flows below 1 cusec. Because of the importance of water measurement in investigation as well as in irrigation and drainage practice, efforts are being continued in association with Central Experimental Workshops to find a satisfactory device, particularly for small flows.

Investigations on drainage and reclamation have been concentrated mainly during the past year on further examination of responses of river-deposited material to drainage by pumping from deep-seated sand strata. In the Renmark Irrigation Area a second bore located 50 chains from the first has now been fitted for pumping. Investigations are in progress to determine the extent of interaction following pumping from the two bores, and the joint area of influence. In addition, two bores have been put down in another part of the Renmark district which includes a larger proportion of lighter soils than those in the vicinity of the earlier bores. All recent bores in this district have been put down to depths of the order of 80 feet.

Investigation of deep-seated strata will be facilitated by use of a boring rig now being assembled, which has been designed to drive and jet 2-in. casing to a depth of 200 feet if necessary. The equipment comprises a 2-ton trailer, fitted with a mast and carrying a 6 horse-power motor, high and low pressure water pump, air compressor, and crank for operating a 40-lb. hammer.

Preliminary studies have been made of a method of determining the *in situ* permeability of waterlogged porous material. The method involves field work and the use of an electrolytic scale model. It is hoped that it will prove useful in elucidating problems of drainage, particularly in the river areas. Results so far have not been consistent with the original theoretical basis for the method and further tests will be carried out in this connexion.

A pressure apparatus has been set up for investigation of soil moisture potentials under irrigation. A comparison is being made between foamed concrete and plaster of paris blocks for the measurement of soil moisture and moisture potentials.

(*b*) *Land Use.*—By arrangement with the Division of Soils, the Merbein Station has continued to carry out soil surveys of comparatively small areas in the region, especially those proposed for soldier settlement under irrigation. During this year, 326 acres of land at Coomealla, to be irrigated under the War Service Land Settlement Scheme, have been examined.

A renovation trial on land at Woorinen, previously abandoned for vine growing, is now in its third year. The trial is designed to give information on the value of various plant covers in renovating deteriorated land to be planted later in vines or fruit trees, and also to show the value of the various renovating crops to the district as fodder or pasture. In the spring of 1948, portions of the land were treated either with gypsum or with gas-works residue (a cheap source of sulphur) for comparison later with control areas not so treated. After a summer under millet grown under irrigation, six types of plant cover were sown, comprising four pasture mixtures, lucerne, and annual crop.

After reasonable success in establishment, the pasture species perennial ryegrass, cocksfoot, and *Phalaris tuberosa* have been found to need closer attention,

particularly as regards frequency of watering, than can be given under the conditions prevailing in typical dried fruits settlements during the harvest time for vines. Under irrigated annual crops, deterioration of the land continued. Accordingly, in autumn, 1951, the whole trial area was planted to lucerne. A smaller trial, including similar pasture and lucerne treatments, is being continued in its original form on the local Inquiry Committee's experiment farm.

Trials of gypsum, sulphur, and gas-works residues as soil ameliorants on areas of failing vines on two of the major soil types at Woorinen have been in progress for two years. An improvement in vine health has been noted with the change from furrow to flood irrigation that accompanied the institution of the trial. While the first harvest gave indications of improvement from both gypsum and sulphur, the second year of the trial was rendered abortive because the vines went seriously short of water during a critical period of the summer.

Methods for determining the boron content of irrigation and drainage waters have been investigated. Of various colorimetric reagents tested, 1,1'-dianthrimide was found the most satisfactory for the smaller concentrations of boron. Where the boron content exceeds 1 p.p.m., the quinalizarin method gave the best results.

(*c*) *Horticulture.*—Investigations have been continued on the factors involved in the variation in yield from year to year of the sultana vine. Bunch counts carried out in October, 1950, substantiated the forecast made during the previous May for a low percentage fruitfulness of sultana buds for the 1950-51 season. Although weather conditions at harvest were almost ideal, the crop was one of the lightest for years. For the 1951-52 season, bud examination made in May, 1951, showed that the percentage fruitfulness is higher than it was last year, and potentialities exist for a crop up to average in yield.

Examination of the data obtained in detailed studies of the bud burst on 81 vines in the spring of 1949 has been completed. It was found that the number of buds which burst each day was correlated with the maximum temperature of the previous day. During the period of bud burst, the fruitful shoots tend to emerge before the barren shoots, so that there is a linear decrease with time of the percentage of fruitful buds among the total buds bursting each day. Percentage of fruitful shoots, average green weight of fruit per fruitful shoot, and average length of both fruitful and unfruitful shoots have been found to bear relationships to bud position capable of expression as mathematical formulae, conforming in each case with a parabolic distribution.

Trial of 2,4-D sprays as a substitute for cincturing of the currant vine was extended this year to larger areas on several private vineyards. This method continues to show promise of developing into a procedure of practical importance.

A trial was commenced to examine the effect of time of application of "Lime Sulphur" spray (1:10) for the control of "shoot restriction disease" on sultana vines. Separate plots were sprayed on three occasions at fortnightly intervals during the month before bud burst. All sprayed vines sprouted and grew normally, while the control vines showed some symptoms. In this season, however, the incidence of the disease was not sufficiently serious to affect the crop on the control areas.

Control of weeds at minimum expense continues as a matter of lively concern to vine growers and others. In a test commenced last year, "Hormex" at two strengths was used in an attempt to control hardhead (*Centaurea picris*) in a vineyard. The weaker of the two solutions (0.3 per cent.) appeared to be the more effective in reducing growth, and one spray this season kept the weed under control. The indications are that the amine salt of 2,4-D will keep hardhead under control relatively inexpensively. Under the conditions of trial, similar considerations apply to bindweed (*Convolvulus arvensis*).

Although weedkillers of the 2,4,5-T type were tried this year, camel thorn (*Alhagi camelorum*) has not yet been controlled successfully under the conditions prevailing in the region. The use of the more volatile ester compounds of 2,4-D and 2,4,5-T against weeds among vines is precluded because of the damage done to vines by their vapours.

A survey of Woorinen vines and soils, first carried out in April, 1950, was repeated in modified form in March, 1951. Relations are being sought between the health of sultana vines at each sampling point and the salt content and pH of soil and the leaf composition in terms of contents of chloride, boron, and nitrogen.

The effect on plant growth of increasing sodium in the clay complex in a selected Woorinen subsurface soil has been tried out in a preliminary way by growing sultana cuttings in pots of treated soil. In order to evaluate the effect of high pH as such, an attempt was made also to grow sultana cuttings and rootlings in culture solutions representing the wide pH range. Experience gained in these methods will be valuable in future culture work.

Further work has been done on the relation between soil salinity and the salt status and yield of the vine, with chloride as an indicator of salinity. Most of this work has been done on a medium-textured soil, Coomealla loam, which is undrained and bears sultanas showing various degrees of salt injury. The indications, mainly from sultanas, are of close relationships between soil chloride, the chloride content of whole leaves or petioles from middle positions on shoots, and chloride content of canes sampled in winter. Expressed as percentages of the dry weight, the chloride concentrations of the petioles are approximately twice those of the whole leaves. The trunk, sampled in winter, is variable, but there is an increased chloride storage in the weaker vines.

It has been found that the rise in chloride content of petioles during the season is not affected by irrigations. A further point of interest is that rain may reduce petiole chloride concentrations so that this figure for samples taken after January may not be reliable as an indicator of excessive soil salinity. For undrained Coomealla loam, if chloride content of middle petioles is greater than 1.1 per cent. on the dry basis in early November, 1.7 per cent. in early December, or 2.3 per cent. in early January, yields from vines are extremely low. For vines showing such figures in December and January, severe burning of basal leaves occurs and the younger leaves may be affected also. A start has been made on the examination of sites on light, medium, and heavy soil types to find whether the threshold chloride value, above which yield is depressed, varies with soil type.

Statistical analysis of the results of a survey of boron content of whole sultana leaves (lamina plus petiole) throughout the Sunraysia district showed a correlation between boron content and soil type, vines growing on the lighter soils giving much lower figures than those on the heavier soil types. Vines in the Curlwaa area had lower boron content than those on mallee soils. There was a very slight correlation between boron content and chloride content of vine leaves. During the 1950-51 growing season, concentrations of boron up to 1,600 p.p.m. of the dry matter were recorded for sultana leaf laminae from vines on heavy, poorly drained soils. Petiole concentrations were found not to exceed 200 p.p.m.

Weekly measurements of the circumference of Valencia oranges were carried out in 1950 from January to October to obtain growth rate curves. During the winter months there were several serious recessions in growth rate, which would probably affect the final size of the fruit. The winter of 1950, however, was abnormally dry, and similar conditions may not recur frequently. Measurements are being carried out again in 1951.

Following a series of detailed observations and measurements on the growth of citrus shoots, a paper has been published describing the various types of shoot and their relation to the growth of trees and the production of fruit.

Although green manuring has been a standard practice in orchards and vineyards for many years, there are a number of aspects on which scientific information is imperfect. During the past year further data have been sought on some of these points, and trials have continued of alternative green manures to take the place of tick beans where growth of the latter has been poor. On very light sandy soils where tick beans failed to produce satisfactory crops, it was found that *Lathyrus ochrus* and tares (for a later crop) were good substitutes.

The indications are that both *Lathyrus ochrus* and tares have higher nitrogen contents than beans sampled at the same time. The tendency, therefore, would be towards more rapid availability of nitrate after turning in these crops than with beans. Laboratory investigation of relative nitrification rates is in progress.

Percentages of total nitrogen in soils sampled from the Merbein Station manurial trial were very significantly greater from green manured plots than from those not subjected to this treatment. This finding is being checked on a further set of samples taken in autumn, 1951. In conjunction with soil samples taken at intervals during the season to provide an estimate of the rate of breakdown of tick bean residues under field conditions, leaf samples were taken from vines of the various nitrogen treatments on the Merbein Station manurial trial in an effort to determine at what growth stages vines require maximum supplies of nitrogen. Analysis is proceeding on these samples and on others collected in the district from highly manured blocks and also from unmanured blocks for comparison.

(*d*) *Plant Nutrients.*—Results from the 1950-51 dried vine fruits harvest from field trials with commercial fertilizers on vines are in process of statistical analysis, but it is apparent that only on the Merbein Station manurial trial was there a conclusive increase from ammonium sulphate last season. In the other long-established trials—organic versus inorganic nitrogen and phosphorus on light ground at Red Cliffs and on heavy ground at Woorinen—there appear to be no significant increases in yield for last season from the treatments applied. An experiment on time of application of ammonium sulphate and another on the effect of application of potassium fertilizer on sultana quality also gave inconclusive results in the past season.

Indicator plots to show deficiencies of mineral nutrients were planted throughout the district in winter and spring 1950. Primary shoot dieback attributed to zinc deficiency was widespread among flax plants in these plots. A chlorotic condition, similar to iron deficiency chlorosis already observed on established crops, was shown by pea plants on some sites. Wheat plants exhibited an interveinal chlorosis. These conditions failed to respond to spot treatments with sprays and thread injections of salts of zinc, magnesium, manganese, and iron. Maize plants from spring-sown plots showed chlorosis of the growing point with pronounced interveinal chlorosis and dying of lower leaves. These symptoms correspond closely with those associated with "white bud" of maize, a condition known to be due to zinc deficiency.

Investigations have continued on the influence of zinc on the Gordo blanco grape, with special reference to seed formation, development of the berry, and yield. The effect of pruning level on the results obtained by swabbing pruning cuts with zinc sulphate solution is being examined. It is proposed to carry out further work on the distribution of zinc within the vine.

Iron deficiency chlorosis in vines and fruit trees has been investigated during the past six years. It has been found that the chlorosis is associated with soils of high pH and that affected vines or trees usually can be cured or greatly improved by means of cover crops. For vines, the winter cover crop was allowed to remain until November before rotary hoeing, all deep working being eliminated. For fruit trees, a permanent cover crop of lucerne was grown. Vines and trees have remained healthy on sites where these methods of management were commenced in 1946. It has been found that cover cropping with lucerne has had no effect on pH of air-dried soil samples, but there is evidence to suggest that *in situ* pH is lowered. It is proposed to investigate the effect of cover crops on *in situ* pH and on the soil atmosphere, and their relation to iron deficiency chlorosis.

(*e*) *Fruit Processing.*—Work in connexion with the drying of sultanas has included studies of—(i) oil emulsions for use in the cold-dip process; (ii) bulk hot dipping; (iii) substitutes for mineral oil in packing-house treatment; (iv) rotproofing of hessian used in fruit drying. This work is described in Chapter XII., Section 13.

(*f*) *Vegetables.*—In co-operation with officers of the Division of Plant Industry, vegetable investigations and plant studies have been conducted for several years on an area at Red Cliffs. Because of rapid increase in the population of the root-knot nematode in the Mildura district in recent years, close attention has been given to this problem, especially in connexion with tomatoes.

Investigations since 1948 on the control of root-knot nematode of the tomato by soil fumigation with "D-D" (an approximately equal mixture of 1:3 dichloropropene and 1:2 dichloropropane) have been completed. It has been shown that the effect of soil fumigation in control of the nematode is due to reduction in infestation below the level at which yield is affected. A dosage rate of 200 lb. of "D-D" per acre did not achieve 100 per cent. kill in the initial treatment; increase in nematode population in the trial area was so rapid that further treatment was necessary after the second year to avoid significant yield losses of tomatoes. Further findings were that the rate of nematode population increase was constant and independent of initial nematode infestation and that the time interval necessary between fumigation treatments was a function of the rate of nematode population increase and of the level of infestation after the first fumigation.

Because of the expense of soil fumigation, work is proceeding with the object of developing a variety of tomato resistant to root-knot nematode and having all desirable agronomic qualities. Seed of tomato lines reported to be resistant and to be compatible with *Lycopersicon esculentum* has been received from overseas. Crosses have been made with popular varieties and tests under field conditions on infected areas have been begun recently. Results so far are encouraging.

Studies are in progress to determine the extent of hybrid vigour in the F_1 generation of tomato crosses with particular reference to early yield, total yield, fruit size, and quality. Parents considered suitable for commercial glasshouse culture have been selected for crossing. One season's results have been obtained and are in process of statistical examination.

Investigations have been continued on *Lathyrus ochrus*. A replicated trial to test this legume, new to the district, against tick beans has been established at

Red Cliffs. The trial covers two times of sowing, each with three seeding rates of the two legumes. In addition, plots under practical conditions have been established on growers' properties on various soil types in the district.

Seed of canaigre (*Rumex hymenosepalus*), which has been suggested as a possible source of supply for tannin, has been introduced for trial in Australia and a small pilot plot has been put in at Red Cliffs to study its growth habits under the local climatic conditions.

(*g*) *Large-scale District Problems.* — Committees appointed by Commonwealth or State authorities continue to give consideration to large-scale district problems in the Murray irrigation areas.

Waterlogging and soil salinity contribute to a varying extent to the deterioration of portions of the irrigated land in districts such as Tyntynder and Cohuna, and the information assembled by investigating authorities is brought under review periodically so that methods of dealing with the problems can be modified to the best advantage.

Field trials for the purpose of assessing the comparative production capacities of the chief soil types of the district have been established for some years by the Wakool Land Use Committee. The annual report of the committee for the current year presented a comprehensive account of observations on these plots since their inception.

3. Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales.

In addition to studies relating directly to irrigation and soil salting, the Research Station at Griffith has major projects in soil physics, plant physiology, and horticulture. The latter includes a detailed field experiment (Farm 466) in which tree development and yield of oranges under various cultural, irrigation, and fertilizer practices are being studied. This experiment is at a very interesting stage, and the research activities of the Station are being focused on it in an attempt to interpret the more significant initial findings of the experiment.

(*a*) *Irrigation.*—Changes in soil moisture in citrus orchards under different treatments of frequency and rate of irrigation and cultural management are being followed by frequent sampling on the experimental plots. This will enable information to be obtained on the relationship of the state of moisture stress or abundance in the soil on the one hand and tree health, rate of fruit development, and general tree responses on the other.

In addition, winter water requirements of orchards are being determined.

(*b*) *Drainage.*—Waterlogging and salting of soils in semi-arid and arid regions usually accompany their irrigation, and these problems are fairly widespread on the Murrumbidgee Irrigation Areas. Methods of investigation and control have been determined largely by whether or not artificial under-drainage has been possible.

Drainability studies to determine the best depth and spacing for tile drains have been carried out on most soil types liable to water-logging and salting. Results from these studies have been applied in laying down one farm-size tile-drainage trial, where a close check is kept on the health and yield of the plantings, and on the changes in the salt content of the soil and drainage water. The effect of the tile-drainage system on the general water-table fluctuations is also watched. Each year the drainage system removes large quantities of excess water and soluble salts, and after two years' operation it appears to have arrested the downward trend in plant health. A second farm-size tile drain is being installed this winter.

Pumping from wells or bores located in pervious strata offers an alternative method of under-drainage. Techniques which have a bearing on this method are being tested where soil and geological conditions appear to be suitable.

An important theoretical problem is the path which the soluble salts, particularly sodium chloride, take when they rise to the soil surface, and thereby destroy plant life. In an attempt to solve this problem, use is being made of a radioactive isotope of sodium. The solution of this theoretical question is expected to assist the design of control measures.

(*c*) *Chemistry.*—The work on salt injury to citrus has now been concluded.

An investigation has been begun on the effect of irrigation and cultivation treatments on the plant nutrient status of local soils. Nitrate and ammonia determinations have been made on soil samples taken at different depths, and laboratory soil nitrification studies have been carried out. Initially this work is to be centred upon the citrus field experiment (Farm 466) already mentioned.

(*d*) *Soil Physics.*—The Soil Physics Section is working on soil structure problems associated with the conditions imposed on the soil by irrigation. The methods for measuring soil structure have been investigated and a procedure has been developed which facilitates routine structure analyses of soils. The measurement of structure stability is receiving special attention because of the confusion existing in that field. Structure stability as determined by several methods is being examined in relation to soil clay and organic matter content.

The effect of reconditioning treatments on soil structure, for example the growing of certain crops, has been measured, and glasshouse and field experiments are now being used to determine the effect of these new structure states on the growth of economic crops.

Investigations are also being carried out to determine the relationships between the various soil properties, and the resistance of the soil to the packing forces of agricultural machinery. At the same time the creation of still more stable aggregation by compressive forces is being investigated with a view to improving the process of soil cultivation.

(*e*) *Horticulture.*—In the factorial field experiment (Farm 466) there are no major changes in the yield data. Of the cultural practices being tested, the oil spray treatment continues to produces healthier trees and better yields than all others, but within the treatment there are indications that nitrogen is now in short supply where the fertilizer is withheld. The severe depression of growth in the weeds-mown treatment is now considerably alleviated where sufficiently heavy dressings of nitrogen have been applied. The remaining two cultural treatments, both of which include summer clean cultivation, continue to show no response to nitrogen. Tree health and yields are good. Information which may lead to the interpretation of these effects of cultural treatment is being sought by the techniques of soil physics and soil chemistry and by leaf analysis.

In the work on the reconditioning of old orchard land, four methods of reconditioning are being compared. These were laid down in old peach land and old vine land in 1945. In the spring of 1950 the old peach land was replanted with peaches, and the first season's growth indicates that the treatments have had little effect. There is a wide variation in health among the trees of the young orchard, however, and the areas of poor health closely follow the pattern of unhealthiness and dying-out indicated in an aerial

photograph of the original planting. Some work is being done to seek reasons for the poor health of the young trees.

The Murrumbidgee Irrigation Areas are marginal with respect to the hazard of frost damage to citrus, and the work with wind machines is being continued. A horizontal-axis machine embracing two 40 horsepower motors has been installed in a citrus grove, but satisfactory testing cannot be completed until damaging frosts are experienced. Preliminary trials, however, give confidence that the machine will give some protection to a relatively large area of trees.

These investigations are being conducted in conjunction with the Section of Meteorological Physics, and further details are given in Chapter XXVII., Section 5.

(*f*) *Vegetables.*—Recent attention has been focused almost exclusively on the nutrient requirements of the main vegetable crops of the Areas. The nutrient most commonly deficient is nitrogen. Available forms of this element are extremely mobile and supplies to the crop are difficult to maintain. The conditions under which the land is held prior to planting have been found to be most important in determining the nitrogen-supplying powers of soil.

The accumulation of phosphatic fertilizer residues has been further studied. A survey of horticultural farms was carried out to determine whether phosphatic residues have accumulated extensively throughout the Areas, and to ascertain the degree of association of citrus "mottle-leaf" and high phosphate status of the soil. Many farms were found to have blocks requiring no further phosphatic fertilizer, a result of generous dressings in the past. The severity of "mottle-leaf" (induced zinc deficiency) was found to increase generally with the available phosphate level of the soil, but the relationship was not clear-cut.

A quick test for available phosphorus suitable for field use was developed and related to standard laboratory methods.

The movement of applied phosphorus in columns of soil has been studied in the laboratory, and important influencing factors were shown to be the rate of application, the type of soil, and its physical condition.

The main soy-bean trial conducted on behalf of the Section of Plant Introduction failed to germinate satisfactorily under wet conditions this year. However, a subsequent establishment trial threw some light on several factors affecting germination of soy-bean seed. The effect of sowing depth and seed disinfection varied with the soil moisture levels in the pre-emergence period.

(*g*) *Plant Physiology.*—The plant physiology section has continued its work on soil fertility and plant water relations, and a project involving foliar analysis of citrus from Farm 466 has been started.

(i) *Soil Fertility.*—This work is mainly concerned with the effects of rice hulls as an organic soil amendment on the growth of field crops. Three distinct types of plant response to this organic fertilizer are now recognized, viz. an adverse effect on germination, a setback in seedling growth, and a subsequent stimulation of growth such that the final yield exceeds that of the control.

Adverse effects of organic fertilizers on growth, especially in early stages, have been reported frequently, and the usual interpretation is that, in the course of microbial decomposition of the organic matter, there tends to develop an acute competition for soil nitrogen and a consequent setback to plant growth. Analysis of the growth of tomato seedlings week by week, however, suggests that this condition develops only some weeks after sowing, presumably after seed reserves of nitrogen have been exhausted.

A still earlier adverse effect of rice hulls is due to a delay in germination and possibly also in early establishment.

The earlier indications that the subsequent stimulation of growth of plots treated with rice hulls is due to an increased intake of phosphorus have been confirmed by chemical analysis of plant samples from the experimental plots.

(ii) *Plant Water Relations.*—Progress has been made in the study of the effects of light and severe wilting treatments on the growth of individual leaves, stems, and roots of the tomato plant and the statistical treatment of the weight data from two such experiments is now complete.

The nitrogen data of the first experiment show that treatment has greatly affected the distribution of this element throughout the plant. Of special interest is the fact that leaves which had completed their development when they were subjected to a period of wilt responded differently to treatment from leaves which were developing rapidly at that time. In general, it may be said that the intake of nitrogen by the plant was interrupted by the wilting treatment, but that two weeks later these plants contained as much nitrogen as the control plants, and the percentage content was greater than in the controls.

(iii) *Foliar Analysis.*—Citrus leaf samples are being collected at six-monthly intervals (three occasions) from 256 of the test trees of Farm 466. These samples are to be analysed for several nutrient elements by rapid colorimetric procedures. It is believed that this chemical servey of a complex factorial experiment will assist in the interpretation of the considerable effects of the four cultural treatments and their interactions with the level of nitrogen supplied as sulphate of ammonia.

V. ANIMAL HEALTH AND PRODUCTION.

1. General.

Research into problems of animal health and production and studies in the sciences yielding knowledge basic to investigation of problems within the animal industry of Australia have continued to form an important part of the Organization's activities. This work is undertaken within the Division of Animal Health and Production, which has its administrative head-quarters in Melbourne, Victoria.

Division of Animal Health and Production.—The major activities of the Division have been, as in the past, concerned with problems of the sheep and cattle industries, but poultry breeding has received considerable attention. A general outline of the programme of work is given in this chapter and in addition some of the results obtained from sheep and wool investigations are mentioned in Chapter VII. Sections 3, 5-7, 9, and 12-19, and those from cattle investigations in Chapter VIII., Sections 2, 3, 5, and 6.

Co-operative work with other Divisions and with some of the Departments of Agriculture and the Universities in the several States and Federal Territories has continued to play an important part in the activities of the Division.

The programme of work carried out at the main research centres of the Division is set out below.

2. Animal Health Research Laboratory, Melbourne.

(*a*) *Pleuropneumonia of Cattle.*—Research has been continued on this disease and a prophylactic vaccine for use in the industry has been produced (*see* Chapter VIII., Section 2 (*a*)).

(*b*) *Tuberculosis of Cattle.*—A limited amount of work only has been carried out during the year (*see* Chapter VIII., Section 2 (*b*)).

(*c*) *Mastitis in Dairy Cattle.*—Research has continued on this disease (*see* Chapter VIII., Section 2 (*c*)).

(*d*) *Haematuria vesicalis of Cattle.*—Research has continued in the laboratory on this problem (*see* Chapter VIII., Section 2 (*e*)).

(*e*) *Anaplasma centrale.*—The strain of *A. centrale* was maintained in a viable condition for at least 739 days at −80° C. when last tested (*see* Chapter VIII., Section 2 (*f*)).

(*f*) *Brucellosis of Cattle.*—During the year an experiment on the comparative value of tail and subcutaneous inoculation of strain 19 vaccine was completed along with intensive studies on the disease (*see* Chapter VIII., Section 2 (*d*)).

(*g*) *Physiology of Milk Production.*—The inhibition of milk secretion by the development of pressure within the udder has been under study. The development of suitable techniques has proved difficult. Although progress has been made, the difficulties have not been fully overcome. Progress was made in the collection of sets of identical twin heifers for experimental animals. By the end of the year eleven sets had been collected.

(*h*) *Caseous Lymphadenitis of Sheep.*—The experiments mentioned in previous reports have been continued (*see* Chapter VII., Section 15 (*a*)).

(*i*) *"Toxaemic Jaundice" of Sheep.*—The co-operative investigation of heliotrope poisoning and chronic copper poisoning of sheep has been continued (*see* Chapter VII., Section 15 (*b*)).

(*j*) *Toxicity of Wheat for Livestock.*—The experiments have been continued (*see* Chapter VII., Section 7).

(*k*) *Physiology of Reproduction in Sheep.*—Research on several aspects of the physiology of reproduction in sheep has been continued (*see* Chapter VII., Section 12).

(*l*) *Microbiological Chemistry.*—During the year studies were completed on the strain of *Lactobacillus.* Preliminary experiments were carried out on *Indigofera enneaphylla,* which had been shown by experiments in the Northern Territory and Queensland to cause Birdsville disease of horses. The results of the experiments showed that the plant does not produce disease as a result of an antithiamin effect. A major study of the nutrition and metabolism of the micro-organism which causes pleuropneumonia of cattle was begun during the year.

3. McMaster Animal Health Laboratory, Sydney.

(*a*) *Parasitological Investigations on Internal Parasites.*—Studies on anthelmintics were continued and extended to include additional work on phenothiazine; observations on the epidemiology of worm infestations in sheep were commenced in co-operation with the Departments of Agriculture in Western Australia and Tasmania; studies on resistance and immunity to worm infestations were continued and further progress has been made (*see* Chapter VII., Section 16).

(*b*) *External Parasites of Sheep.*—Some estimations have been made of the quantity of insecticide recoverable from the fleece after spraying and "fogging" and some additional observations were made on the control of ectoparasites by insecticidal fogs (*see* Chapter VII., Section 17).

(*c*) *Blowfly Strike Problem.*—Several field trials were carried out, involving some 8,000 sheep, but no conclusive results were obtained because blowflies were relatively inactive (*see* Chapter VII., Section 18).

(*d*) *Parasite Physiology and Toxicology.*—This work has been continued and some usefnl progress has been made (*see* Chapter VII., Section 16 (*d*)).

(*e*) *Nutrition Studies.*—Additional studies have been made on digestive processes in the rumen, the mechanics of drought feeding of sheep, and the effects of nutrition on the breeding performance of Merino ewes; further data have been collected covering stall-feeding of beef cattle (*see* Chapter VII., Sections 3 and 6, and Chapter VIII., Section 6 (*c*)).

(*f*) *Biochemical Studies.*—Studies on carbohydrate metabolism in ruminants have been extended to include consideration of the effects of dietary variations on the production and absorption of the products of ruminal digestion (*see* Chapter VII., Section 5).

(*g*) *Physiology of Reproduction.*—Detailed observations on the mechanisms of fertilization and early segmentation of the ovum have been continued and extended to include histochemical studies (*see* Chapter VII., Section 12).

(*h*) *Section of Mathematical Statistics.*—The officers of this Section who are attached to the Division are housed at the McMaster Laboratory. They have continued to play an active and most valuable part in the planning of experiments and in the analyses and interpretation of results. The Senior Research Officer-in-Charge of this work is a member of several of the research teams, including those conducting the sheep-breeding trials and the strain trials within the Division. The results of some of the work are incorporated in the outline of work given in Chapter VII., Sections 13 (*d*) and 19 (*b*).

4. Veterinary Parasitology Laboratory, Yeerongpilly, Queensland.

The Veterinary Parasitology Laboratory of the Division of Animal Health and Production was established at Yeerongpilly, Brisbane, in 1948, to undertake investigations into parasites affecting livestock, particularly those of importance in Queensland. The laboratory also accommodates some officers of the Division of Entomology who are engaged in investigations into the bionomics and control of the cattle tick, *Boophilus microplus.* Close co-operation with the State Department of Agriculture and Stock in all research problems is maintained and is assisted by the Joint Veterinary Parasitology Committee (Queensland). The research programme of the officers of the Division of Animal Health and Production has included the following studies during the year.

(*a*) *Epidemiology of Parasitic Gastro-enteritis of Cattle.*—These studies, commenced three years ago, are being continued in co-operation with the Department of Agriculture and Stock (*see* Chapter VIII., Section 3 (*a*)).

(*b*) *Faecal Examination as a Measure of Helminth Infestation in Cattle.*—Further progress has been made in these investigations, particularly in relation to the influence of the growth of the host and the increasing faecal output on the egg production of helminth populations (*see* Chapter VIII., Section 3 (*b*)).

(*c*) *Studies on Liver Fluke.*—Studies have been continued on this fluke in cattle in Queensland and information has been obtained on its incidence and distribution. Observations have also been made on this parasite in South Australia, with particular reference to its snail intermediate host (*see* Chapter VIII., Section 3 (*c*)).

(*d*) *Studies on Amphistome Flukes of Cattle.*—Studies on the identification of the species of amphistomes infesting cattle have been completed and the information obtained has added considerably to knowledge on the life cycles and economic importance of the respective species (*see* Chapter VIII., Section 3 (*e*)).

(*e*) *Studies on Methods of Administration of Anthelmintics to Cattle.*—Physiological studies on methods to ensure the direct passage of anthelmintics into the abomasum of cattle have been continued.

(*f*) *Worm Nodules* (Onchocerca gibsoni) *in Cattle.*—Further work on this parasite cannot be attempted until the insectary, which is provided for, becomes available.

(*g*) *Studies of Hydatid Disease of Cattle in Queensland.*—These studies have been continued and information has been obtained on the incidence and distribution of the disease (*see* Chapter VIII., Section 3 (*d*)).

(*h*) *Control of Body Strike in Sheep.*—In co-operation with the Division of Entomology and the Department of Agriculture and Stock, further field trials with DDT and BHC for the control of body strike in sheep were carried out (*see* Chapter VII, Section 18).

(*i*) *"Queensland Itch" of Horses.*—The distribution of "Queensland itch" in Queensland shows it to be confined to that part of the State east of a line through Cunnamulla, Longreach, and Hughenden. Considerable progress has been made into the etiology of this disease and the evidence obtained strongly supports the hypothesis that the condition is associated with hypersensitivity to the bites of sandflies (Ceratopogonidae). One species of *Culicoides,* at present unnamed, is especially concerned: it has a distribution similar to that of the disease and is confined in its attack to the regions of the body on which the lesions occur. Susceptible horses confined in an insectary during the hours 4 p.m. to 7 a.m. do not contract the disease. Affected horses recover in four to six weeks when treated in this manner and relapse when released. Supporting evidence is given by the blood-histamine picture: susceptible horses after enclosure in the insectary show no rise in blood histamine, but exposure to night-biting sandflies immediately gives the typical reactions previously reported. Encouraging results have been obtained by treating affected horses with histamine azoprotein. Protection of the animal by regular spraying with DDT is being investigated.

(*j*) *Studies on Tick Toxins.*—Investigations are being continued to ascertain whether or not a cross immunity can be obtained with the toxins present in the eggs of Australian species of Ixodid ticks. The possibility is being explored of the serum from animals immunized against the toxin in the egg of *Boophilus microplus* being of value against tick paralysis caused by *Ixodes holocyclus.* Investigations have shown that guinea pigs may be readily killed by emulsions of the eggs of *I. holocyclus, Haemaphysalis bispinosa,* and *Boophilus microplus.* There was some evidence that with the eggs of *B. microplus,* on which most work has been done, an immunity may be established in animals by giving them graded doses. It appears, however, that the toxin in the eggs of these species, including *I. holocyclus,* may not be identical with the toxin causing tick paralysis, because paralysis did not occur in any of the experimental animals.

(*k*) *Studies on the Taxonomy of the Ixodid Genus Aponomma.*—Species of *Aponomma* are normally found in Australia on several species of reptiles, on the spiny ant-eater, and on the wombat. Occasionally, however, specimens are encountered on livestock. Considerable difficulty in the identification of these species has been encountered, as only the original descriptions are available. A revision of the genus showed nine species to be present in Australia, three of which are regarded as new.

5. F. D. McMaster Field Station, Badgery's Creek, New South Wales.

The work of the Station has been largely devoted to the development of hybrid dairy cattle based on Zebu crosses with British breeds. The breeding studies on sheep have also been continued.

(*a*) *Study of Inbred Flocks of Australian Merinos.*—*See* Chapter VII., Section 13 (*a*).

(*b*) *Study of the Inheritance of Component Fleece Characteristics.*—*See* Chapter VII., Section 13 (*b*).

(*c*) *Study of the Inheritance of "Hairiness" and "Fluffy-tip" in Sheep.*—*See* Chapter VII., Section 13 (*c*).

(*d*) *Studies on "Fleece Rot".*—*See* Chapter VII., Section 15 (*d*).

(*e*) *Study of Hybrid Dairy Herd.*—*See* Chapter VIII., Section 5.

6. Wool Biology Section, Sydney.

(*a*) *Comparative Studies of Breeds of Sheep: An Experimental Study.*—The experiment to study Merino, Corriedale, Polwarth, and Lincoln breeds was continued (*see* Chapter VII., Section 14 (*a*)).

(*b*) *Comparative Studies of Breeds of Sheep: Field Studies of the Skin and Fleece.*—The systematic studies have been continued (*see* Chapter VII., Section 14 (*b*)).

(*c*) *An Analysis of Skin and Fleece Characters in Ewe Progeny of Top Sires in an Australian Stud.*—This study has been continued (*see* Chapter VII., Section 14 (*c*)).

(*d*) *Experimental Histology of Skin and Hair Growth: The Analysis of Hair-follicle Types in Tissue Culture.*—A tissue-culture unit has been established in the Section and a study of two follicle types by the culture technique was begun (*see* Chapter VII., Section 14 (*d*)).

(*e*) *Experimental Histology of Skin and Hair: Nutritional Requirements for Hair Growth in Tissue Culture.*—These nutritional studies were also started by the use of the tissue-culture technique (*see* Chapter VII., Section 14 (*e*)).

7. Regional Pastoral Centre and Laboratory, Armidale, New South Wales.

The co-operative work of several Divisions of the Organization and the Department of Agriculture of New South Wales at this Centre has been continued but has been hampered by lack of progress in the establishment of laboratory and housing facilities. Nevertheless, work on plants and animals has been carried out. The research programme of the Division of Animal Health and Production during the year was as follows:—

(*a*) *Field Investigations of the Control of Body Strike in Sheep. See* Chapter VII., Section 18 (*a*).

(*b*) *Blowfly Strike in Sheep: Studies on Lamb-marking Dressings. See* Chapter VII., Section 18 (*b*).

(*c*) *Study of Strains of Merino Sheep in Several Environments.*—The environment of the "Chiswick" Field Station is being used as one of three environments for the study (*see* Chapter VII., Section 13 (*e*)).

(*d*) *Studies on Neo-natal Mortality in Lambs. See* Chapter VII., Section 19 (*a*).

(*e*) *The Effects of Grazing Management on Pasture and Animal Production.*—This co-operative investigation with the Division of Plant Industry has been continued (*see* Chapter III., Section 13 (*a*), and Chapter VII., Section 19 (*e*)

(*f*) *Internal Parasites of Sheep. See* Chapter VII., Section 16.

(*g*) *Winter Feeding of Weaners.*—In 1950, the body-weight gains and worm burden of weaners entering the winter in "poor" and "store" condition, grazing on improved pastures were compared. The weaners in poor condition made greater body-weight gains than those in store condition. Worm burden in both groups was low.

(*h*) *Studies on Animal Behaviour.*—These studies have been continued. It has been found that sheep in experiments with a flock size of two spend more time in walking and less time in feeding than sheep in larger flock sizes.

(*i*) *"Staggers" in Sheep.*—During the year an outbreak of "staggers" occurred in sheep grazing a phalaris-clover pasture. A trial was designed to elucidate the factors associated with this type of disturbance, which is sometimes observed in pastures containing *Phalaris tuberosa*.

8. National Field Station, "Gilruth Plains", Queensland.

The second half of 1950 continued wet and mild and by December no less than 31.1 inches of rain had been received, making the year the wettest on record: the mean annual rainfall for the Cunnamulla district is 14.1 inches. However, the second half of the 1950-51 period has been extremely dry, as only 3.10 inches of rain have been recorded since the middle of November, 1950. Temperatures during the summer of 1950-51 were very high and the excellent feed of late 1950 dried off completely. Blue grass (*Dichanthium sericeum*) dried completely and the Mitchell grasses (*Astrebla* spp.) showed their real value as a drought-resisting species. Seedling Mulga (*Acacia aneura*), which germinated and grew so well during the last four favorable years, has been providing much fodder for the sheep. With the exception of some old experimental ewes, all stock has remained in surprisingly good condition.

A short but intense wave of blowfly body-strike was experienced in the early summer months and up to 28 per cent. of some flocks became affected. Crutch strike was entirely absent and, although serious mortalities were prevented, loss of wool was appreciable. In view of this severe blowfly strike prior to and during lamb marking a percentage of 81.0 lambs from 2,919 breeding ewes was satisfactory. At shearing in early April, returns of wool per head were low but this is directly attributable to loss of wool through fly strike and the high proportion of aged experimental ewes.

The various sheep-breeding trials have progressed satisfactorily. The major project—breeding systems investigations—is now in its fifth year and much valuable information is being obtained. The second project—strain trial—moved into its second phase in 1951 with the mating of the F_1 generation. Many interesting and valuable results are now becoming available. The top cross trial was resumed again in 1951 with the mating of ten inbred rams to flock ewes. Because of limited facilities this trial will be transferred to Deniliquin (*see* Chapter VII., Section 13).

Investigations into lamb mortality have continued and there is an increasiug amount of evidence that lamb losses between birth and marking are considerably greater than has been generally appreciated. Attention here has been directed towards an accurate dissection of the causes of mortality and the results suggest that at least one form—dwarfedness—may be a simple recessive character transmitted by the sire. Observations during 1950 indicated that the mortality of lambs during the first six weeks of life was about 20 per cent. Once again it was observed that a high proportion of these losses were of multiple birth.

The two main projects of the Division of Plant Industry at "Gilruth Plains"—grazing management and pasture regeneration studies—were continued. These trials are now in their fifth year of operation and they will reach finality in October, 1951 (*see* Chapter III., Section 15).

9. Fleece Analysis Laboratory, Chester Hill, New South Wales.

This laboratory continued to carry out the large number of physical measurements on the fleece of sheep that were required in the experimental biological work of the Division of Animal Health and Production. Investigational work was also carried out. Work has been carried out for the Wool Measurement Laboratory of the New South Wales Department of Agriculture which is situated at Trangie. Later the laboratory at Trangie came into operation and was able to undertake all but a small portion of the work.

During the year, 20,864 measurements were made, including scouring tests, measurements of mean diameter by cast and by slide technique, determinations of density of fibre population, and measurements of crimp and staple length. In addition, 42 measurements were made of cattle hair for length/diameter analysis, 36 for wax and suint, and 179 for the determination of weight per unit area. The techniques remained very much the same as last year. The laboratory participated in further inter-laboratory tests organized by the American Society of Testing Materials and, as in the previous year's tests, the results obtained were very satisfactory.

Investigational work was continued. Methods of diameter measurement were under investigation with a view to the development of a more rapid one. Methods of measurement of surface area of the skin of sheep were investigated. Further work on length analysis of samples by the automatic length analyser and on "gating circuits" was carried out and satisfactory results were obtained. A start was made on the determination of the factors affecting the efficiency of the drying of scoured wool by air blasts, partly with a view to the development of a quicker and more efficient oven for drying the wool samples. The work was also designed to provide some basic information for driers in woollen mills as well as to secure experience in heat-transfer measurements in wool and fleece. A preliminary study of the character of "softness" of handle was started. Out of many samples of wool, of the same mean fibre diameter, a few were found which were graded differently for handle fairly consistently. These samples were selected for further detailed study. A start was made in collecting equipment and in developing techniques for the investigation of heat and moisture transfer through the live fleece under various environmental conditions.

10. Poultry Research Centre, Werribee, Victoria.

Further progress was made during the year in the development of the Poultry Research Centre at the Division's Field Station, Werribee, Victoria. The addition of a trapnest house and a grain silo will complete the building programme. The housing accommodation has been brought to a capacity for a flock of 4,428 birds. The experimental flock on 1st May, 1951, had been increased to 3,077 female and 320 male birds. The programme of research work has remained unaltered and steady progress has been made.

(*a*) *Investigation of Breeding Systems.*—The fifth generation was hatched in 1950. The annual records of the birds hatched in 1949 (D series) have been analysed. Briefly, the results have shown: (i) that crossbred pullets from Leghorn and Australorp breeds produced two dozen eggs more than their better parent-breed; (ii) that a three-way cross gave the same good results as the simple cross; (iii) that outstanding results were obtained with a backcross to a Leghorn male from Australorp x Leghorn dams; (iv) that some significant progress in egg production was made within the three groups in which selection was based on progeny testing; (v) that phenotypic selection based on conformation did not improve egg production; (vi) that selection can be based on partial winter records; (vii) that selection for early maturity or intensity of laying seems more promising than selection for absence of

winter pause; and (viii) that inbreeding up to a coefficient of inbreeding of 40 per cent. has not produced any harmful effects in the flock of White Leghorns.

(*b*) *Physiology of Reproduction and Inheritance of Fecundity.*—Some progress was made with the maintenance of fertilizing capacity of stored semen by centrifuging it and suspending the sperm in Tyrode solutions for inseminations. Experiments showed that the plasma of the semen can be substituted by Tyrode solution without impairing fertilizing capacity. Intraperitoneal insemination showed that infertility in some females is caused by conditions in the oviduct preventing sperm from reaching the ovum. The bacterial flora of semen was studied and the class of the bacteria determined. A study was started on the effect of light intensity on egg production, as encountered in different positions of laying cages in the battery houses.

(*c*) *Biometrical Method for Measuring Performance.*—The study mentioned in the previous Report was extended and revised.

(*d*) *Inheritance of Characters.*—The results of the study mentioned in the previous Report were prepared for publication.

11. Other Investigations.

(*a*) *Investigation of Beef Production in Australia.*—(i) *Survey of Beef Cattle Production.*—This survey was completed (*see* Chapter VIII., Section 6 (*a*)).

(ii) *Studies on the Bovine Skin.*—These studies were continued (*see* Chapter VIII., Section 6 (*b*)).

(*b*) *Survey of Fine Wool Production.*—The survey was continued but was interrupted for a period during the autumn months (*see* Chapter VII., Section 19 (*c*)).

VI. NUTRITION.

1. General.

The Organization's work in the field of general nutrition is largely devoted to studies of the nutritional physiology of the ruminant, and more especially to the nutrition of sheep and to the influence of nutrition on wool production. The experimental investigations are conducted by the Division of Biochemistry and General Nutrition, which has its head-quarters and laboratory situated within the grounds of the University of Adelaide.

The surprisingly small inheritance of basic knowledge of these subjects, which are obviously of fundamental importance to the efficient conduct of the great pastoral industry, has been materially increased by these researches. The findings arising from them have found immediate and widespread application in the industry, through a close and understanding liaison between the Division and the State Department of Agriculture and other bodies whose duties and interests are to apply the findings of research to the pastoral industry.

The remainder of this chapter gives a brief account of the work of the Division. Further details of the studies on various aspects of the nutrition of sheep are to be found in Chapter VII., Sections 2-5, 8, 10, and 11, and of the application of plant nutrition studies to the development of the Ninety-mile Desert, now renamed Coonalpyn Downs, in Chapter III., Section 22.

2. Nutrition and Wool Production.

Studies of the relationship between nutrition and wool production have been extended. This work is briefly reviewed in Chapter VII., Section 2.

3. Metabolic Studies.

The series of experimental investigations which aim to illuminate the chemical mechanism through which the sheep deals with its fodder are commented upon in Chapter VII., Section 3. The primary reason for these studies is to provide the basic information which will extend our understanding of the reactions of the animal to various fodder conditions. Without this knowledge there is little hope for a solution of the many problems associated with metabolic disorders that beset grazing ruminants.

4. Vitamin A Requirements of the Sheep.

The study of the vitamin A requirements of the sheep has been continued. Some of the details of the current experiments are briefly reviewed in Chapter VII., Section 8. Under Australian pastoral conditions, the most probable nutritional disability that is likely to arise from vitamin deficiency would be imposed on grazing stock by the extreme shortage of vitamin A in the sun-bleached, dry pastures which periodically comprise the sole fodder for the herds and flocks. These experiments are designed to extend the rather poor fund of knowledge of the reactions of sheep to a serious shortage of vitamin A in the fodder.

5. Effects of Chronic Fluorosis.

In certain areas in Australia where the stock is watered from deep artesian wells, disabilities which supervene on the chronic ingestion of small amounts of fluorine are experienced. The experiment designed to extend existing knowledge of chronic fluorosis in the sheep is described in Chapter VII., Section 10.

6. The Amino Acid Constitution and Structure of Wool from Copper-Deficient Sheep.

These studies, which have been referred to in previous reports, have been completed and are in course of preparation for publication. They illuminate further the physiological mechanisms responsible for keratinization of the wool fibre.

7. Biochemical Studies of the Disordered Metabolism in Zinc- and Copper-Deficient Plants.

(*a*) *Phosphorylation.*—The investigations of the effects of zinc and copper deficiency on the biochemical processes involved in phosphorylation within the tissues of plants have been continued. The findings reported last year were confirmed: the zinc-deficient plants contained more phosphate but the labile-phosphate concentration did not differ from that of the normal controls or of the copper-deficient plants.

The investigations are at present awaiting the completion of a glasshouse which will be utilized for the production of suitable experimental material.

(*b*) *Aldolase.*—Zinc-deficient plants have been suspected of having abnormal carbohydrate metabolism, but there has been no indication of the metabolic defect responsible for it. An examination of the activity of the enzyme aldolase revealed that it is very seriously decreased in the tissues of zinc-deficient plants. As this enzyme effects the reversible conversion of fructose 1,6-diphosphate to the trioses, phosphoglyceraldehyde and dihydroxy-acetone, a partial breakdown in its efficiency could account for the disordered carbohydrate metabolism in the zinc-deficient plant.

(*c*) *Tryptophan-forming Enzyme.*—An unsuccessful search was made in green plants for evidence of the existence of an enzyme which has been reported to effect the synthesis of tryptophan from indole and serine in the mould *Neurospora crassa*. The activity of this enzyme has been reported to be reduced in the tissues of zinc-deficient *Neurospora*.

8. Minor Elements in Nutrition.

The study of the nutritional importance of minute quantities of cobalt, copper, zinc, molybdenum, &c., both in animals and in plants has been continued. These experiments have considerably advanced knowledge of the physiological roles assumed by these

elements and have led to widespread applications in the pastoral industry, which are of considerable economic moment. Further details of those of the researches which concern the disabilities brought about by deficiencies of cobalt and of copper in pastures are referred to in Chapter VII., Section 11. Besides these, a number of experiments designed to extend knowledge of the functions of these elements are in progress in the laboratories of the Division. A comprehensive study is being made of metabolism of zinc in plants and animals. Rations that are complete in all respects but practically devoid of zinc have been prepared. Rats confined to these will grow normally if supplemented with zinc, but in the absence of additional zinc they will cease to grow and will develop specific lesions of the integument and of the hair. The metabolic defects that occur in the zinc-deficient animals are being sought. These experiments are being continued. Special attention is being given to the effects that zinc deficiency exerts on the production of hair.

Further studies have been made of the effects which supervene in rats confined to copper-deficient rations. The first series, which was mainly concerned with the effects of molybdenum in the metabolism of copper, has been completed and a full report of the results is being prepared for publication. The metabolic defects that are brought about by copper deficiency are being studied.

9. Plant Nutrition.

The studies of mineral nutrition which led to the development of the Ninety-mile Desert are being continued in order to solve a number of problems associated with particular soil types of this region. These experiments are described in more detail in Chapter III., Section 22.

10. Accessory Food Factors.

The main activity of this section of the nutritional studies has been conducted during the past year in Cambridge and in London by the officer responsible. Special attention was given to the recent developments of microbiological methods for the estimation of pantothenic acid and of the cobalt-containing vitamin B_{12}.

11. Radioactive Isotopes.

C^{14} and Co^{60} have been employed as tracers in a number of experimental investigations which concern various aspects of rumination and of the intermediary metabolism of fatty acids. The use of radioactive isotopes is now established in this Division as a useful technique.

12. Field Stations.

(*a*) *Glenthorne.*—The experiments to determine the effects of molybdenum on the metabolism of copper in the sheep were continued throughout the year and have now been completed. These are discussed in Chapter VII., Section 11 (*b*). Experiments to extend further the knowledge arising from these have been begun. The experiments concerned with chronic fluorosis have been continued, and are described in Chapter VII., Section 10.

This site has been further developed as labour and materials have become available. The year was a dry one, and the ewes and lambs were provided with hay and grain to supplement the pastures. The 202 strong-woolled Merino ewes mated in November, 1950, dropped 205 lambs, of which 175 are surviving. A number were used for physiological investigations. From 30 ewes in the small, fine-woolled flock only eighteen lambs were born, of which twelve survive. Thirty acres were sown to wheat and cut for hay, 10 acres were sown to oats and 40 acres of fallow were prepared. An additional 100 acres of permanent pastures were sown. Water restrictions limited the production of lucerne hay to 10 tons from the two acres. Molybdenum deficiency has been proved on one of the soil types which comprise this area, and in order to increase the status, 160 acres of pasture were top-dressed in April, 1951, with superphosphate containing sufficient molybdenum sulphate to provide 1 oz./acre.

(*b*) *Other Field Stations.*—The field investigations of the effects of minor element deficiencies have been continued at the Division's field stations at Robe, Keith, Borrika, Glenroy, Kybybolite, and "Brecon", and are discussed in Chapter VII., Section 11 (*c*)-(*h*).

VII. SHEEP.

1. General.

Investigations on sheep have continued in the Divisions of Animal Health and Production and of Biochemistry and General Nutrition. The activities of these Divisions are outlined in Chapters V. and VI. The work of the Division of Animal Health and Production on sheep is described in Sections 3 (*i*), 5 (*a*), 6, 7, 9, and 12-19 of this Chapter and that of the Division of Biochemistry and General Nutrition in Sections 2, 3 (*a*)-(*h*), 4, 5, 8, 10, and 11.

Much of the Organization's work on soil infertility and pasture improvement, described in Chapters II. and III., is also of importance to the pastoral industry.

The work of the Organization's Wool Textile Research Laboratories is described in Chapter XV.

2. Nutrition and Wool Production.

The relationship between the state of the sheep's energy balance and the efficiency with which the animal utilizes the protein in its fodder for wool production has been further investigated in the Division of Biochemistry and General Nutrition in a series of experiments which are now nearing completion. The results, which will be discussed in a forthcoming publication, established the physiological laws which govern protein and energy metabolism of the sheep, and so simplify the understanding of the many factors which influence wool and meat production by animals grazing in the diverse conditions of the Australian environment. This firm foundation of knowledge will allow an approach to be made towards solving the major problems of increasing the overall efficiency with which the animal converts its foodstuffs to wool, flesh, milk, &c. The "normal" efficiency of these conversions is low and might be increased materially before the physiological limitations imposed by the digestive processes are reached. A new series of experiments along these lines is projected.

3. Processes of Rumination.

(*a*) *Intermediate Stages in the Production of Volatile Fatty Acids in the Fermentation of Wheaten Hay.*—Extension of the investigations by the Division of Biochemistry and General Nutrition previously reported has demonstrated that in the mixture of acids formed by fermentation of fodder *in vitro* with the mixed population of organisms which inhabit the rumen, the proportion of propionic acid decreases during the first few hours when the rate of acid production is at a maximum. The composition and rate of production of acid thereafter remain fairly uniform. At no stage is the proportion of acetic acid as high as it is in the rumen fluid.

(*b*) *Detailed Analysis of the Volatile Fatty Acids in the Rumen Fluid.*—The mixture of volatile fatty acids in the rumen has been shown to include all the saturated fatty acids from C_1 to C_6, and probably C_7, together with some of the isomers of the higher acids, and determinations have been made of the proportions in which they are present.

(*c*) *The Origin of the Higher Volatile Fatty Acids in the Rumen.*—When acetic acid labelled with C^{14} in the carboxyl group was incorporated in the rumen fermentation *in vitro*, active carbon appeared later in all the higher acids examined. When C^{14} carboxyl-propionic acid was included in the fermentation, C^{14} appeared in the valeric acid but not in the butyric acid. The qualitative and quantitative results suggest that a large part of the butyric and valeric acids in the rumen is synthesized from acetic and propionic acids by condensations with a 2-C compound in equilibrium with acetic acid.

(*d*) *Bacteriology of the Rumen.*—Following the work reported above, isolation of the organisms responsible for the synthesis of the higher acids in the rumen has been begun.

(*e*) *Absorption of Fatty Acids from the Rumen.*—The previous Report referred to the use of labelled fatty acids for the purpose of determining the relative rates of absorption of the acids through the rumen wall. Because of the occurrence of the reactions described in Section 3 (*c*), they could not be used in this way. However, the evidence previously held to suggest that the permeabilities of the acids are dependent on their concentrations in the rumen, has now been shown to be unsound. The changes in the composition of the acid mixture in the rumen after the inclusion of an additional amount of one of them were evidently influenced to a marked degree by the continued production of acid even when the animals had been fasted for 24 hours, and the bulk of solids had been removed. When fermentation was reduced to a minimum by centrifuging the fluid, the absorption of the acids was found to conform to the findings originally reported for pure acids introduced into the empty rumen.

(*f*) *Starch-like Polysaccharides ("Starch") in the Rumen and Abomasum.*—The work proposed in this field was outlined in the previous Report. The concentrations of "starch" (the origin of which, from fodder and/or from the micro-organisms of the rumen, has not yet been determined) and of lignin in the rumen have been measured at intervals throughout the 24 hours. The information obtained in this way allows an estimate to be made of the amounts of "starch" which pass to the abomasum. The investigation has been extended to include the determination of "starch" and lignin in the abomasum, in order to assess by other means the amount of "starch" which passes out of the rumen.

(*g*) *Passage of Fatty Acids to the Abomasum.*—Investigations are being made to decide whether significant quantities of the fatty acids reach the abomasum from the rumen. The object of this work is to test the claims of other workers that practically all of the fatty acids are removed from the rumen material by the omasum and that no absorption of fatty acid occurs in the abomasum.

(*h*) *Utilization of Urea.*—The experiments with sheep in pens to determine the possibility of utilizing urea in lieu of protein concentrates in supplementary feeding practice for wool production, mentioned in previous Reports, have been completed.

The projected field trials with grazing sheep that were mentioned could not be started during the year owing to floods and considerable stock losses in the area where it had been decided to conduct the experiments. Arrangements have now been completed, however, and the experiment is to be commenced in the early spring, immediately after shearing. The Queensland Department of Agriculture and Stock and the Division of Biochemistry and General Nutrition will co-operate in this series of experiments, which will be located at an experimental station recently established by the Department in north-west Queensland.

(*i*) *The Effect of Diet on Digestive Processes in the Rumen.*—Diets containing carbohydrate, protein, and roughage in several different proportions have been fed to sheep and the digestive processes in the rumen studied at the McMaster Animal Health Laboratory. On all diets, consistent changes in the proportion of lower fatty acids in the rumen liquor were observed after feeding. Acetic acid decreased to as low as 55 per cent., whereas propionic and butyric acids increased. There was a return to a fairly constant pre-feeding level. However, if the reaction fell below pH 5.2, the trends in the proportions of lower fatty acids present were not consistent, owing probably to different effects on groups of bacteria in the rumen. These bacterial groups include two concerned with production of lactic and butyric acids respectively, one with proteolytic activity, and a fourth responsible largely for deamination of amino acids. With diets containing an excess of protein over "available" carbohydrate, ammonia nitrogen was found to accumulate in large quantities in the rumen. This accumulation was suppressed by the addition of "available" carbohydrate. However, it was found that ammonia nitrogen accumulation is not a simple function of the protein content of the diet. Lactic acid was found to accumulate in the rumen when the diet is rich in starch or soluble sugars. Lactic acid accumulation was found to be the end result of the interaction of many factors.

4. Energy Metabolism.

The energy metabolism of sheep subjected to relatively long terms of semi-starvation is being investigated as a part of the experiments on nutrition and wool production mentioned in Chapter VI., Section 2. The results of these experiments are directly applicable to drought-feeding policy.

The basal rate of energy dissipation was observed in previous experiments to recede materially in sheep subjected for a period to rations which were insufficient to provide the fuel necessary to fulfil the requirements of the animal. Critical experiments are now being conducted to determine the relationship of this change to the energy deficit, in order to provide knowledge of considerable theoretical and practical importance.

5. Carbohydrate Metabolism.

Work on carbohydrate metabolism has continued in the Division of Animal Health and Production and the Division of Biochemistry and General Nutrition.

During the past year an officer of the latter Division visited Great Britain and worked for some months in the Physiological Laboratories at Cambridge and Edinburgh. At Cambridge, newly-born calves and goats were used to study various aspects of carbohydrate metabolism. These studies are being continued in collaboration with two workers at Cambridge.

(*a*) *The Carbohydrate Metabolism of Adult Sheep.*—In the Division of Animal Health and Production further results have confirmed the finding that the rate of peripheral utilization of acetic acid depends on its level in arterial blood. There appears to be some depression of this rate when glucose uptake by the same tissues is proceeding at its most rapid rate, but further data are needed to establish the significance of this observation.

Recent evidence has shown clearly that the rate of uptake of glucose by the extrahepatic tissues is increased while the blood glucose is increasing after food intake and is depressed again when the blood glucose is falling. Detailed studies have shown that the rate of extrahepatic utilization of glucose appears to depend not only on the rate of acetic acid utilization but also on the direction of fluctuations in the blood-glucose level. While the blood glucose is increasing the latter exerts the major effect.

The maximum rate of absorption of glucose from the small intestine of sheep is slow compared with that in non-ruminants. After the administration of 10-100 g. glucose into the abomasum, the blood glucose rises slowly to a maximum at about two hours. This maximum is sustained over a period as long as 5-6 hours. Thus the " tolerance " of sheep to glucose administered via the intestinal route in the same way as glucose administered by intravenous injection, is low compared to non-ruminants. The results strongly suggest a lower maximum level of hexokinase activity in ruminant tissues.

There appears no doubt, from the results of experiments, that the liver or other organs, or both, can handle lactic acid, presumably converting it to glucose, in an efficient manner. No consistent rises in blood lactic acid were observed in sheep in which lactic acid accumulated in the rumen after feeding on various diets, even though the levels in rumen liquor reached 500 mg. per 100 ml. and the rate of absorption of other end-products of digestion, e.g. lower fatty acids, was extremely rapid.

Metabolic abnormalities have been observed on certain diets. Increases in blood glucose up to three times and in blood volatile fatty acids up to ten times have been recorded after feeding. On most diets investigated, the level of acetic acid in the blood was closely dependent on the level in the rumen. On certain diets, however, there was evidence on the one hand of greatly increased, and on the other of greatly depressed rates of absorption. Some of these abnormalities are under investigation.

The intermediary metabolism of acetic acid in conjunction with the concurrent metabolism of propionic and butyric acids has been investigated further in the Division of Biochemistry and General Nutrition. When these lower fatty acids were injected intravenously into fasting sheep the concentrations of sugar, ketone bodies, and pyruvic acid in the systematic circulation followed the same trend as was observed in the normally fed animal. The apparent production of sugar after the intravenous administration of butyric acid is being investigated. From analyses of the systemic blood it was shown that insulin may possibly be implicated in the metabolism of the lower fatty acids. The interrelation of the metabolic processes involved in the utilization of these volatile acids is being studied.

(b) The Carbohydrate Metabolism of Newly-born Lambs.—Work was continued with young lambs from the breeding flock at the Glenthorne field station of the Division of Biochemistry and General Nutrition. From determinations made of the concentration of total reducing sugar, fructose, pyruvic acid, and volatile acids in the blood of newly-born lambs, it appears that the metabolic processes of the very young lamb are similar to those of non-ruminants, and so differ in important respects from those of the adult ruminant. The total reducing sugar in blood samples taken from the jugular vein of lambs a few minutes after birth was found to consist of two fractions: glucose, which was present in about the same concentration as in the maternal blood, and fructose, which constituted an additional 30-40 mg. of reducing sugar per 100 ml.

The fructose was observed to disappear from the blood stream within a few hours, irrespective of whether the lamb was allowed to suckle immediately or was withheld from the ewe. The glucose level, however, rises after the lamb has suckled, and it remains elevated for a period of four to five weeks, after which it declines to the normal adult level.

If the lamb is prevented from suckling, the level of pyruvic acid in its blood falls until suckling is permitted, after which there is a sharp but transient rise.

The intravenous administration of glucose to young lambs revealed a tolerance curve typical of non-ruminants. The metabolism of the young lamb is thus not unlike that of mixed feeders and carnivores. The later changes in the metabolic processes are related to the supply of fatty acids which follows when the rumen develops and functions.

6. Drought-Feeding Experiments.

The experiments on sheep feeding, with particular reference to drought conditions, which are being conducted by the Division of Animal Health and Production at Glenfield, New South Wales, in collaboration with the New South Wales Department of Agriculture, have been continued. The work is now financed partly from the Burdekin Bequest, administered by the New South Wales Graziers' Association, and partly by the Organization. The results obtained are recorded briefly as follows.

(a) Daily Compared with Weekly Feeding.—All experiments have provided further and conclusive evidence that when adult dry sheep are being hand-fed for survival, it is good sheep husbandry to feed them weekly. A total of some 700-800 adult Merino wethers have been used in these trials.

(b) Comparison of Wheat with Grain Sorghum as Drought Fodders.—Experiments were carried out in which groups of wethers were fed on 10:90 mixtures of wheaten chaff and grain, the grain being supplied as wheat, whole grain sorghum, or crushed grain sorghum. The results have not yet been fully analysed, but they appear to indicate that wheat was slightly superior to grain sorghum and that crushed sorghum was superior in feeding value to the whole grain. However, the differences were not great enough to warrant any special effort to obtain wheat if grain sorghum is available, or to favour the additional labour and cost of crushing grain sorghum.

(c) The Influence of Exercise on Food Requirements at Drought-feeding Levels.—It has been believed that under drought conditions sheep waste their energies and increase their food requirement by wandering in search of feed. Groups of full-mouthed Merino wethers on drought rations were therefore driven slowly over a 3.24 mile course daily for a period of some five months, during which they travelled 280 miles. Other groups which received the same quantity of feed were not exercised. At the conclusion of the trial there was no significant difference between the exercised and unexercised groups in body weight, survival rate, or general condition.

(d) Post-drought Feeding for Restoration of Body Weight.—At the termination of drought-feeding experiments the sheep were regrouped to uniformity and were fed *ad lib.* on the following mixture:—lucerne chaff 30, oats 70; lucerne chaff 30, wheat 70; wheaten chaff 30, wheat 69, ground limestone 1; wheaten chaff 30, wheat 59, linseed meal 10, limestone 1; wheaten chaff 30, wheat 67, urea 2, limestone 1. Another group was turned out to graze on improved pasture. Food intake of the different mixtures varied widely. Lucerne chaff and oats were consumed most readily and the sheep thrived best on them. The mixture containing urea was the least palatable. The group which grazed on improved pasture regained weight at about the same rate as the sheep which were fed on wheaten chaff, wheat, and linseed meal, whereas in a similar trial in 1950, grazing gave very inferior results. This was probably because high rainfall produced feed which was over-succulent. Little experimental information is available on this, but it is a matter of considerable importance in sheep husbandry, especially in the colder and wetter districts of the southern States.

7. Toxicity of Large Rations of Wheat.

When hungry sheep in poor condition consume wheat grain in excess of about 60 g. per kilogram of body weight, i.e. 3 lb. for a Merino which has fallen in

weight to 50 lb., acute deaths may occur in more than 20 per cent. of the flock. The nature of the fatal illness had remained unknown until its study was undertaken by the Division of Animal Health and Production. It was believed that knowledge of its nature and mechanism might not only lead to safer and less laborious methods of feeding wheat to sheep, but would be of fundamental value to the studies of ruminant digestion.

The investigation has established the fact that the fatal illness is a consequence of an abnormal domination of the ruminal fermentation by lactobacilli which give rise to excessively high concentrations of lactic acid in the rumen and other regions of the bowel to which the wheat has passed. This is followed by a large increase of lactic acid in the blood and by severe acidosis. It has still to be determined how far the lactacidaemia and acidosis are the result of direct absorption of lactic acid from the bowel at rates greater than the animal can utilize it, and how far they are a consequence of the severe blood concentration and suppression of urine excretion which always occur. The present evidence suggests that both factors operate. However, the essential role of the lactobacillary fermentation in the illness is indicated by the finding that the antibiotic aureomycin, given with an otherwise fatal dose of wheat, completely prevented the illness. In these experiments with aureomycin, the reaction in the rumen did not fall below pH 6.2, lactic acid did not rise above 300 mg. per 100 ml., concentration of the blood was negligible, and there was neither lactacidaemia nor acidosis.

8. Vitamin A Requirements.

The experiment mentioned in the last Report was continued. The lambs were weaned at the age of approximately one month, and the ewes were offered the basal ration which supplied approximately 10 γ carotene/kg. body weight per day. After a period of approximately eight months, during which the levels of vitamin A in the blood fell from 20-30 γ/100 ml. plasma to approximately 10 γ, and all but two animals appeared to be nightblind, the small flock of ewes was divided into four groups each of five animals and given sufficient dehydrated lucerne meal to bring the intake of carotene to 25, 50, 75, or 100 γ/kg. body weight per day. The animals were then mated. During the next five months the levels of vitamin A in their bloods rose to approximately 20 γ/100 ml. plasma in the group receiving 25 γ carotene/kg. body weight per day, and to approximately 30 γ/100 ml. plasma in the other groups. One ewe died during this period but the others remained in good health throughout. Lambing is now in progress and the indications are that an intake of 50 γ carotene/kg. body weight per day is sufficient for satisfactory reproduction. This confirms the results obtained previously in the investigation. It is not yet clear, however, whether an intake of only 25 γ/kg. body weight per day is sufficient for satisfactory reproduction.

9. Vitamin D Supplements.

Further work was not conducted on vitamin D supplements during the year.

10. Chronic Fluorosis.

The experiments mentioned in the last Report were continued. Drinking water containing either 0.3, 10, or 20 p.p.m. fluorine was supplied to three groups of lambs born of ewes which had received similar water throughout the period of gestation. The lambs were weaned approximately ten months after the commencement of the experiment. The same supplies of drinking water were offered to three groups of mature wethers which grazed in the same paddocks as the weaners.

During the year there were no significant differences between the increases in weight of the three groups of weaners or between the weights of wool obtained from the three groups at the first shearing. Periodical examination of the incisor teeth has not revealed signs of fluorosis in the deciduous teeth of any of the groups. No permanent incisors have as yet erupted. The experiment is being continued.

There have been no significant differences between the live weights or the wool production of the three groups of mature wethers during the first ten months of the observation experiment. No lesions of fluorosis have yet appeared in the incisor teeth. The experiment is being continued.

11. Minor Elements in Animal Nutrition.

(*a*) *Cobalt Metabolism in Ruminants.*—(i) *Prevalence of Cobalt Deficiency.*—Unequivocal evidence from experiments conducted at several sites, and from general observations, proves beyond doubt that nutritional disabilities imposed by cobalt deficiency are much more prevalent among flocks and herds than is generally realized. The untoward effects suffered by sheep confined to cobalt-deficient fodder vary widely in degree according to the season, the type of soil, and the nature of the pastures. The intensity of the symptoms ranges from the acute and fatal malady through a series of sub-acute states, the milder of which affect only the young animals, to an incipient state of deficiency which, after having no appreciable effect for many years, may, with a change of season, become manifest in a sub-acute or even acute form. This latter condition is transient and, like the milder form in which no obviously specific symptoms appear, is frequently attributed to causes other than a shortage of cobalt in the fodder. The economic consequences are serious and steps are being taken to inform pastoralists of these effects, which periodically appear in areas generally considered secure in respect to cobalt.

(ii) *The Function of Cobalt in Ruminant Nutrition.*—Experiments have been reported previously which proved that cobalt exerts no apparent physiological function if it is injected into the blood stream of the animal: to be effective it must be provided *per os*. The suggestion that cobalt exerted its activity through its influence on the micro-organisms which inhabit the paunch has been proved correct by the demonstration that cobalt administered into the abomasum, either by injection or via permanent fistulae, had no effect on the progressive syndrome of cobalt deficiency which developed in sheep confined in pens and fed on cobalt-deficient rations. The same quantity of cobalt administered *per os* or injected directly into the rumen was completely effective.

It is probable that a considerable quantity of cobalt is essential for the production of vitamin B_{12}, and perhaps of other accessory food factors, by the rumen flora, and that when this quantity falls below a certain level, which has been defined by experiments discussed below, the animal suffers the physiological disabilities associated with deficiencies of vitamin B_{12} and perhaps of other vitamins. There is no evidence that cobalt *per se* has any physiological role in the tissues of the animal itself.

(iii) *Cobalt Deficiency and Vitamin B_{12}.*—Depot therapy with potent liver extracts and with the crystalline cobalt-containing vitamin B_{12} administered to sheep on cobalt-deficient pastures had little or no effect on the progress of the deficiency syndrome. The quantities of vitamin B_{12} employed were of the same order as those utilized in the treatment of pernicious anaemia

in humans, and might well have been insufficient. The effects of greatly increased doses are now being investigated.

(iv) *The Quantity of Cobalt Necessary for Complete Nutrition of the Sheep.*—Previous reports of long-term experiments with sheep on cobalt-deficient pastures at Robe indicated that a supplement of 0.05 mg. cobalt per day was just sufficient to maintain ewes in good health. This quantity has now been proved to be similarly effective for lambs. As these pastures contain between 0.02 and 0.03 microgram of cobalt per gram dry weight it may be implied that the quantity of cobalt necessary for the sheep is probably between 0.07 and 0.08 mg. cobalt per day, and that a fodder containing between 0.08 and 0.10 microgram of cobalt per gram is probably about the lower limit of security in respect to cobalt.

(v) *Control of Cobalt Deficiency.*—Previous experiments have stressed the necessity of frequent dosing with cobalt for the treatment of flocks depastured on deficient terrain. Relatively huge doses of cobalt administered at intervals of one month, however, appear to be effective. The experiments on which this latter finding is based are being continued and the conclusion must be considered tentative. The effects on the health of the flocks which supervene on the application of cobalt to the pastures at Robe and at Glenroy are discussed in Section 11 (*c*) and (*f*). At neither site was this procedure completely effective.

(*b*) *Copper Deficiency in the Sheep.*—(i) *The Effect of Molybdenum on the Copper Metabolism of Sheep.*—Under the grazing conditions that prevail on the copper-deficient terrain at Robe, the equivalent of 50 mg. molybdenum per day administered as molybdate tends to decrease the rate of depletion of copper from the liver, to maintain the concentration of copper in the blood, and, paradoxically, to precipitate sooner, and in most flagrant form, the symptoms of copper deficiency. This latter influence may be overcome by an additional supplement of copper. At the end of two years, there was no evidence of ataxia among the lambs. These ewes have again been mated.

Under the different grazing conditions at Glenthorne, similar amounts of molybdenum had no influence on the concentration of copper in the blood and tended to deplete the animal's stores of copper.

Clearly, then, it is only in circumstances not yet fully understood that ingestion of molybdenum tends to deplete the animal's copper reserves. The factors concerned are being investigated both with experimental flocks depastured at different sites and with small experimental animals under carefully controlled conditions in the laboratory.

(ii) *Control of Copper Deficiency in Sheep.*—Experiments with flocks in the field and with sheep confined in pens indicate that infrequent dosing with relatively massive quantities of copper will maintain a normal copper status in sheep on copper-deficient rations.

(iii) *The Influence of Chronic Ingestion of Molybdenum on the Copper Status of the Rat.*—Experiments with rats have been used to illuminate several aspects of the metabolism of copper which present problems with flocks on copper-deficient terrain. These have proved conclusively that molybdenum under certain circumstances tends to increase the concentration of copper in the tissues but to decrease its availability for some, at least, of the animal's physiological requirements. A series of experiments is being conducted to indicate the factors responsible for this.

(iv) *The Influence of Molybdenum and Tungsten and Other Elements on the Copper Metabolism of Sheep.*—A series of experiments with sheep confined in pens and fed on incipiently copper-deficient rations has shown that whereas the chronic ingestion of molybdenum will reduce the concentration of copper in the liver, similar quantities of tungsten have no such effect.

A critical method for the estimation of microgram quantities of tungsten has been perfected and applied to a study of the absorption and excretion of tungsten. The sheep deals similarly with moderate amounts of tungsten and molybdenum. The effects of other metals on the metabolism of copper are being investigated.

(*c*) *Field Experiments—Robe.*—A number of the experiments described above have been carried out at the Field Station at Robe. In addition, the following experimental trials are being conducted there.

(i) *The Effect of Dressing Copper-deficient Pastures with Copper Sulphate.*—The copper status of sheep depastured continuously on copper-deficient pastures that had been treated with 14 lb. of copper sulphate per acre in 1940 has been determined periodically by liver biopsy. The mean concentration of copper in the livers of the control animals was 46 p.p.m.; in the livers of the animals that had received a supplement equivalent to 5 mg. copper per day while grazing under identical conditions, it was 450 p.p.m. The lowered copper status assessed in this way was consistent with the somewhat lowered general health and productivity of the unsupplemented animals.

(ii) *The Effect of Dressing Cobalt-deficient Pastures with Cobalt Sulphate.*—Without a supplement of cobalt no lambs have been reared and few ewes have survived in the experimental flock that has been confined to pastures to which 1 lb. cobalt sulphate per acre was applied in 1944. The grasses which comprise the pastures there are unable to accumulate sufficient cobalt to meet the nutritional requirements of grazing ruminants, even when the cobalt concentration of these soils is increased.

(iii) *Copper-deficient Lesions in the Wool of English Breeds of Sheep.*—After the sojourn of one year on copper-deficient pastures the signs of copper deficiency have appeared in the fleeces of Border Leicester and Romney Marsh sheep. The wool of the Lincoln and the Dorset Horn breeds has not obviously changed.

(*d*) *Field Experiments, Keith.*—At the end of 1950, the beneficial effects of a dressing of 7 lb. of copper sulphate per acre applied to lucerne pastures in 1943 were still apparent in the experimental group of sheep that has grazed there continuously. The copper status of the group grazed on immediately adjacent pastures was reduced to low levels and the fleeces showed the typical lesions of copper deficiency whereas the copper status of the individuals on the copper-dressed pasture was satisfactory and the wool was normal.

(*e*) *Field Experiments—Borrika.*—The findings at this experimental site were similar to those referred to above.

(*f*) *Field Experiments—Glenroy.*—In 1950, for the second year in succession, acute cobalt deficiency was encountered in untreated lambs. Comparable lambs confined to pastures which were top-dressed with 1 lb. cobalt sulphate per acre in 1946 showed no symptoms of deficiency. This finding is in contrast to the results obtained during the previous year, when a slight deterioration of lambs on the cobalt-treated pastures was detected. The latest findings indicate that treatment of particular types of incipiently deficient soils with cobalt will protect the flocks from cobalt deficiency for at least several years.

(*g*) *Field Experiments—Kybybolite.*—Neither cobalt nor copper deficiency was apparent in the experimental flocks during the past year.

(*h*) *Field Experiments—"Brecon".*—An area of newly-developed mallee-heath has been prepared for an experiment designed to examine the effects on grazing sheep of three different types of pasture which represent species, or a combination of species, which will be widely employed during the further development of these areas. The sown pastures consist of subterranean clover (Bacchus Marsh strain), lucerne, and a mixture of subterranean clover, lucerne, and *Phalaris tuberosa*. Each area comprises 27 acres and was seeded in 1949 and treated with 187 lb. superphosphate, 7 lb. copper sulphate, and 7 lb. zinc sulphate per acre. Ewes in lamb were introduced to these pastures in March, 1951. Half of the ewes in each paddock are drenched once weekly with 7 mg. cobalt. The seasonal rains were early and "Phalaris staggers" developed in the ewes on the pasture in which *Phalaris tuberosa* was dominant. Only those animals which had not been supplemented with cobalt have so far developed the symptoms. In this group ten of the fifteen animals were very seriously affected and still plainly show the symptoms of nervous disorder. Three have succumbed to the malady. There were no cases in the group which was treated with cobalt. Both groups were selected from the same stock and were depastured together as a flock from the beginning of the experiment in March, 1951. The implications of these findings are being investigated. They may well indicate a means of controlling this malady, which in some years assumes very serious proportions.

12. Infertility and Physiology of Reproduction.

(*a*) *The Influence of Nutrition on the Breeding Performance of Merino Ewes.*—The experiment referred to in the preceding Report dealt with the effects of Ca : P_2O_5 imbalance in the ration of pregnant ewes. Observations were continued throughout a second pregnancy and the ewes lambed again in August, 1950. Their ration had been deficient in carotene (precursor of vitamin A) since they came under experiment in November, 1948, but there was no obvious evidence of vitamin A deficiency until the second lambing, nearly two years later. Then, out of 65 lambs born, 60 were dead or died shortly after birth and many of them had enlarged thyroid glands. Late in this pregnancy the vitamin A level of the ewes' blood was much below normal and some were inoculated with massive doses of vitamin A. This restored the level of vitamin A in the blood, but, at that stage, did not prevent the death of the lamb. Some of these vitamin A-deficient ewes which had received no treatment were retained on the deficient ration and were mated again. Half of them were given a vitamin A supplement and the others served as controls. Lambing has terminated and has produced twelve live lambs from twelve treated ewes compared with one live and eleven dead lambs from the twelve controls. Vitamin A contents of plasma, colostrum, and, in some cases, liver tissues are being determined.

(*b*) *Development of Reproductive Activity in Young Ewes.*—Observations were continued on three groups of ewes which were dropped at four-monthly intervals throughout 1947 and 1948, and mated in successive years following their birth. In 1948, only thirteen of 23 ewes born in the previous spring bore lambs; in 1949, seven out of 64 mated ewes failed to produce lambs, but, in 1950, only one out of 64. In the one group for which figures are available for three seasons the peak of the lambing has advanced from September in 1948 to July in 1949 and to May in 1950. The earlier lambing in 1950 may have been due to the sudden introduction of rams in mid-December, 1949. In previous years the rams had been running with the ewes continuously. These observations have been discontinued.

(*c*) *Infertility in Ewes on Clover-dominant Pastures.*—Reduced fertility in flocks of ewes is a serious problem in some parts of Australia. As described in earlier reports, it occurred for several years, in one of its worst forms, in the Great Southern District in Western Australia. The co-ordinated efforts of research workers in Western Australia and in this Organization led to a better understanding of causal factors. Methods were recommended for keeping the ratio of subterranean clover to grasses in pastures below the dangerous level and for better pasture management. Satisfactory results have apparently followed the adoption of these methods and the use of adequate amounts of superphosphate for the top-dressing of the pastures.

Relevant scientific problems of great importance remain to be studied and the Division of Animal Health and Production has co-operated with the Division of Plant Industry in observing the effect of light, grazing, and fertilizer treatment on the content of harmful oestrogenic material in subterranean clover. Oestrogenic activity of the plant material was determined by the guinea-pig method of bioassay previously described. It was shown that the shading of plants significantly lowered the oestrogenic activity, possibly by reducing the proportion of leafy to petiolar material available, and that the activity of clover collected in September was significantly greater when fertilizer treatment did not include phosphorus, whereas neither calcium nor sulphur exercised any significant effect. The samples had been collected at a particular stage of growth at mid-September in the south-west of Western Australia and it cannot be assumed that similar results would be obtained elsewhere or at different times. It was further shown that the activity of clover collected in early October from an area which received little or no potassium in its fertilizer treatment was not significantly different from that of clover from an adjacent area which had received potassium, and that Dwalganup clover and Bacchus Marsh clover collected in Western Australia in early October showed a similar degree of activity. From such results the importance of different clover species may ultimately be assessed and it may be possible, in retrospect, to relate war-time reduction in phosphate top-dressing of pastures to a high incidence of infertility.

Guinea pigs have again been used as experimental animals in the study of infertility due to ingestion of subterranean clover. Clover of about half the activity of that which had previously produced infertility in guinea pigs when it constituted one-third of their daily ration, was fed at that level to four pairs of guinea pigs over a period of six months. The fertility of the pairs remained at a high level throughout the whole of the period of feeding.

(*d*) *Excretion of Oestrogens by Pregnant Merino Ewes.*—In the investigation of problems of reduced fertility of ewes described in Section 12 (*c*), it became apparent that there were many gaps in knowledge of the normal excretion of oestrogens, among other things, by sheep. In this study, urine and faeces of pregnant ewes were examined in order to determine the amount of oestrogen present. The results showed that, in pregnancy, urinary excretion of oestrogen occurs only in the last few weeks. Faecal oestrogen was found to be absent until fairly late in pregnancy and was generally there in greater amount than in the urine. The levels were lower than those found for other species.

(*e*) *Methods for the Experimental Study of Prenatal Mortality.*—It is possible that infertility in ewes may in some circumstances be associated with pre-natal mortality. A method of using hexoestrol for inducing such a mortality for experimental study has been continued. Although it was confirmed that a single dose of 1-2 mg. usually, and 0.5 mg. occasionally, terminates pregnancy when administered 28 days after

mating, it appears that hexoestrol is much less likely to disturb pregnancy in the later stages, but the evidence is not conclusive. When 135-810 mg. of hexoestrol was administered in a single dose, 8-16 weeks after mating, disturbance of pregnancy was observed at autopsy two weeks later in only a few animals. However, only four of twelve animals which received a dose of 400 mg. during that period gave birth to lambs.

(*f*) *Studies on Mechanism of Fertilization and on Gametogenesis.*—Results of experiments continue to support the conclusion that some form of preparation or capacitation in the female tract is required by the sperm before it can enter the mammalian egg. Investigations are being made to find out the reasons for and, if possible, the nature of this capacitation. It seems clear that the principal barrier for the sperm is the zona pellucida. The physical and chemical properties of the zona and of the other cell membranes are therefore being examined. By histochemical methods the zona has been shown to be a mucoprotein containing a large amount of carbohydrate. It is soluble in dilute acid solutions (rat egg) and in solution having a reducing potential (rat and rabbit egg). Attempts to demonstrate an enzyme in the sperm which will act upon the zona have so far been unsuccessful.

The time relations of the stages of fertilization *in vivo* have been studied in the rat egg. Comparison with data obtained earlier shows that the process of fertilization proceeds about five times as fast *in vivo* as *in vitro* under the conditions of our experiments. The results indicate that, *in vivo,* the sperm may enter the egg and form a pronucleus within one hour after ovulation; the growth of pronuclei takes ten to twelve hours, and the first segmentation generally occurs about 22-24 hours after ovulation. The data are at present being examined statistically.

The maturation of the eggs of the rat and rabbit is being investigated, with special reference to the histological change in the contents of the follicle. The increase in follicle size during the final stages of maturation appears to be due mainly to an accumulation of mucopolysaccharide. The differences in the action of hyaluronidase on the cumulus before and after final maturation can be shown to be due to changes in the intercellular connexions of the follicle cells rather than to any change in the properties of the hyaluronic acid gel.

The development of the spermatid has been studied in rats and rams, with the aid of the phase-contrast microscope. By this means observations have been made on the living cells, thus avoiding the introduction of artefacts which are so prone to lead to misinterpretation of the picture presented by fixed and stained material. The results confirm in general the classical concept of spermateleosis, but a number of minor morphological differences have been found. It has also been possible to see motility of the tail filament long before the formation of a midpiece. This observation is contrary to certain widely-held views on sperm motility.

13. Breeding and Genetical Studies.

(*a*) *Inbred Flocks of Australian Merinos.*—Progeny of the five inbred flocks have continued to show a downward trend in vigour, size, and fertility. The original rams heading the flocks have been succeeded by their most inbred sons. The mean coefficient of inbreeding of the animals in all groups is now 23.1 per cent. and a maximum of 50 per cent. has been reached with some animals. In one group, animals with a coefficient of inbreeding of over 40 per cent. are not surviving. The earlier finding that the inbreeding was not producing uniformity of characterization within the groups has been confirmed. In the top-crossing experiment, the progeny groups from the first matings of inbred rams and unrelated flock ewes had fleece samples taken from them as two-tooths. A further mating has been made in which sires from the inbred families are put with other flock ewes. The sires have been selected as having none and 25 per cent. of inbreeding respectively, and have been drawn in pairs from each family at both degrees of inbreeding.

(*b*) *Inheritance of Component Fleece Characteristics.*—These studies have been continued. The first F_1 progeny in the investigation will have fleece samples taken as two-tooths. The first $F_1 \times F_1$ matings have been made.

(*c*) *Inheritance of "Hairiness" and "Fluffy-tip".*—The studies have been continued. Development of the F_2 population is continuing and fleece samples have been taken for examination.

(*d*) *Study of Breeding Systems.*—The objectives and nature of this investigation have been described previously. The investigation entered its fifth year with the 1951 matings. Rams in the mass selection (phenotypic or individual merit) and control (no selection) groups were mated individually for the first time, as more pens were available than previously, in order to determine and control the degree of inbreeding. Twelve rams were mated in the proven sire group, four sons from each of the three sires originally chosen on progeny test. Six groups were again mated in the family series, in which selection is for or against a single character in each group. This series is now at the stage when up to four generations of ewes are being mated to the head of the family and a high degree of inbreeding is being attained. The Big x Big family in this series is yielding results which show that the progeny are bigger both at birth and at weaning than the average of the whole series.

In connexion with these investigations, the Section of Mathematical Statistics is making a statistical examination of contributing factors derived from both animals and wool. The data include body size and clean wool weight for each animal, and for wool, its fibre diameter, staple length, number of fibres per unit area, and number of crimps per unit length. Scores are also given for degree of wrinkling of the skin on neck and side, and for the amount of wool on the face.

In these studies, the main criterion of production is weight of clean wool of a specified quality, and in considering this factor, its component parts—namely, mean cross-section area, mean length of individual fibres, mean number of fibres per unit area, skeletal surface area, and increase in skin area due to amount of wrinkling or folding—are being examined. The influence of environment on each character is being assessed, and the heritability of each estimated.

By a simple method devised to express the actual measurements of the five characters in terms of percentage deviations (which then add approximately to the deviation of clean wool weight), the source of differences in wool weight between groups of animals can readily be seen. For example, a sire which confers extra wool weight on its progeny solely through increased fibre diameter may not be considered as valuable as one achieving such a result through increased number of fibres. Formerly, the AB1 flock has provided a good many of the data for this analysis, but the method is now being applied more widely.

The relative contribution of each of the characters to variations in clean wool weight between individual animals has been studied, and it has been found that the percentage area of skin covered by fibre (this being derived from cross-sectional area and number of fibres) accounts in the AB1 flock for approximately 70 per cent. of the total variation in wool weight between animals of one sex and age. This analysis also is being extended to cover other strains and breeds.

Although it is still too early to expect positive results for most of the objectives of this investigation, much useful information has been obtained. For example, it is now possible to say that the progeny from "maiden" ewes are inferior to progeny from mature ewes, at least up to the age of two and a half years. Also, now that three offspring by the same ram from the same ewe are available in large numbers, it is possible to determine daughter-dam regressions and the repeatability of sire performance. Both of these determinations are valuable contributions to any animal breeding programme. A stage has been reached when it becomes possible to measure the genetic contribution by both sire and dam. This should have practical value in view of the dominating attention to the sire in all commercial breeding programmes.

(*e*) *The Study of Strains of Merino Sheep in Several Environments.*—Work on this project proceeded satisfactorily at "Gilruth Plains", Cunnamulla, Queensland, and at "Chiswick", Armidale, New South Wales. The second drop of lambs was produced at both centres and observations were commenced on the first year's progeny. Data on body measurements, scores, and wool measurements are being accumulated. Subjective gradings of fleece characters were again made by a worker from the East Sydney Technical College. These gradings are filling an important gap which cannot be covered by the objective wool measurements being made at present. Purchased rams were exchanged between "Gilruth Plains" and Armidale prior to the last mating. A section of the medium non-Peppin strain was transferred from "Gilruth Plains" to Armidale, so that all strains are now represented at each centre. Each of the studs of origin was visited and rams were inspected for general soundness, including the collection of semen samples. Progress was made in the establishment of the third centre, at Deniliquin on an area adjoining the Falkiner Memorial Field Station. Groups of sheep consisting of one-third of those of each strain at the two original centres were transferred, and transfers were started at the end of the year.

At "Gilruth Plains" in the study of some of the reactions of the several strains to the common environment, results have already been obtained suggesting that the level of fertility varies appreciably between strains. For example, the large-framed, strong-wool, non-Peppin, South Australian strain has been outstanding in its performance at lambing, lamb-marking, and weaning, with the small, wrinkly, fine-woolled, New England type at the other end of the scale. Also, during the 1950 season with the unusual rainfall of 31.1 inches, the fine-wool sheep withstood the conditions better than the strong-wool sheep. There has been a trend in the progeny of the extreme types away from their parents. Although it is generally accepted that the degree of crimping is a direct indication of the fineness of the fibre, it has been found during the year that the medium-fine Peppin "B" strain gave a fleece appreciably finer and more dense than the fine-wool non-Peppin strain although the respective crimps per inch were 11.4 and 14.7.

At Armidale, for the second year in succession, continuous heavy rain placed a stress on the sheep and on the management. There was a difference in the reactions to the stress between the groups. The incidence of wool faults such as water stain, fleece rot, canary stain, and cotted fleece was highest in the strong-wool strain (53 per cent.) and lowest in the fine-wool strain (10 per cent.).

14. Biological Studies of the Skin and Wool Growth.

(*a*) *Comparative Studies of Breeds of Sheep—An Experimental Study of Lincoln, Corriedale, Polwarth, and Fine-wool Merino Ewes.*—The second stage of this experiment was completed. The first stage was concerned with the analysis of the fleece and other characteristics of ewes of the four breeds on a standard high-quality ration available in unrestricted quantity. The second stage has been concerned with the changes occurring when the amount of the same high-quality ration was reduced in successive months to 80, 60, 40, and 20 per cent. of the food consumption level attained under the unrestricted régime. The ultimate low level of 20 per cent. was maintained for three consecutive months until equilibrium was established for the main characters measured.

If the value for each character measured at the unrestricted level be taken as an index figure of 100, the ultimate values attained at the end of the experiment for each breed may be summarized as follows:—

Measurement.	Lincoln.	Corriedale.	Polwarth.	Fine Merino.
Clean Wool.. ..	48	35	37	27
Wax	29	26	25	22
Suint	56	37	37	26
Fibre diameter ..	86	67	62	60
Fibre population density (No. per sq. in.)	101	102	103	140
Numerical size of follicle group ..	93	106	91	101
Relative size of primary and secondary fibres	109	114	108	114

It is apparent from this brief summary that when the intake of the standard ration used in the experiment was reduced as low as one-fifth of the self-imposed high level, neither the breeds themselves nor the individual characters measured responded equally. The first four characters in the table are all relatively more unstable in the face of the food intake changes than are the last three characters. Important interactions have also been observed between food intake, air temperature, and the insulating fleece burden in relation to the levels of clean wool, wax, and suint production attained during both the first and the second stages of this experiment.

(*b*) *Comparative Studies of Breeds of Sheep: Field Studies of the Skin and Fleece.*—The study of skin and fleece variation within and between stud flocks of the breeds and strains of sheep important in Australia is being continued on its present systematic basis. With the use of histological and other criteria, this study will continue for several years until a sufficient number of animals have been examined under a sufficient variety of conditions to establish the main limits of phenotypic variation as a background to more intensive biological studies such as that referred to in the preceding section. The programme of study will be expanded in the ensuing year. Apart from this phase, field observations are accumulating to establish some of the main reasons for the differences in response of different fleece types to the important climatic variables of air temperature and air moisture (especially rainfall). Some fleeces, such as those of the fine Merino, appear able to endure considerable extremes of rainfall and temperature without untoward visible or indirect effects. Other fleece types, such as those with attributes similar to the Corriedale, appear more prone to admit moisture, especially rain, and to exhibit endogenous discolorations (such as "canary stain") or exogenous colour changes (such as those due to bacterial activity). An examination of the factors for which the animal is responsible in such cases is a natural part of the comparative breed studies. The focus of interest at present centres on the mode of growth of the fleece staple, the compactness of fleece growth, the character of the skin secretions composing the "yolk", and the physiological

responses of the sheep to certain physical stresses such as the "sweating" response to various combinations of heat, humidity, and insulating fleece burden.

(*c*) *An Analysis of Skin and Fleece Characters in Ewe Progeny of the Top Sires in an Australian Merino Stud.*—This study is being continued by the regular sampling each year of at least twenty single ewe progeny, in order of birth, by each of five sires in the stud. As far as possible, fresh progeny samples by each of the top three sires are taken for each lamb-drop on at least two consecutive years, while each year the progeny of two new rams of special interest are included. This study is based on an examination of skin sections and the related fleece staples from a single body region on each ewe. Results cannot be finalized for at least another two years. In consecutive years a fair repeatability has been noted for any given sire in the values found but environmental influences due to varying seasons, as expected, complicate the interpretation of the data.

(*d*) *Experimental Histology of Skin and Hair Growth: The Analysis of Hair Follicle Types in Tissue Culture.*—Previous work by a member of the Section in overseas laboratories established that both the sensory hairs or vibrissae of the upper lip of embryonic mice and the pelage hairs of the trunk would develop in tissue culture. In the newly established tissue culture unit, the behaviour of the two follicle types has been compared in the uniform environment of culture chambers. Many differences were found between vibrissae and pelage follicles and their hairs during normal development. Skin pieces taken from the upper lip of embryo mice before perceptible follicle formation produced, during cultivation, follicles and hairs with the essential characteristics of vibrissae. Similarly, embryo skin pieces from the trunk taken before follicles were in any way perceptible produced in culture follicles with the essential features of the pelage population. Thus, even before follicles appear, the skin from a particular body region must be "determined" for a particular type of follicle and hair. Such differences are not due to the embryonic or the post-natal environment.

With the routine of skin tissue culture established it should be possible to compare by similar methods the different follicle and fibre types of the sheep, notably the primary and the secondary components of the hair follicle group. It is proposed to attempt this soon.

(*e*) *Experimental Histology of the Skin and Hair: Nutritional Requirements for Hair Growth in Tissue Culture.*—The pelage follicles of embryo mouse skin develop normally when cultivated in a medium of fowl plasma and chicken embryo extract. By varying the concentration of individual nutrients in this medium, their effects on follicle differentiation and fibre growth may be determined. The effects of different concentrations of glucose are being studied.

15. Sheep Diseases.

(*a*) *Caseous Lymphadenitis of Sheep.*—These experiments were designed to determine the value of two methods of control of the disease, an annual pre-shearing vaccination, and the placing of sheep directly "off shears" in a clean rested paddock. The experiment commenced in 1946, and the two groups from that year should have been sent for slaughter in 1950. Unfavorable seasonal conditions caused a delay, but arrangements were made for the slaughter in July, 1951. Further groups of wether weaners were brought into the experiment in 1947, 1948, and 1949, and these should go to slaughter in 1952, 1953, and 1954 respectively.

(*b*) *"Toxaemic Jaundice" of Sheep.*—In earlier Reports, progress of research work performed by the Division of Animal Health and Production with the co-operation of the Veterinary Research Station, Glenfield, New South Wales, in the field and with the assistance of other Divisions of the Organization and State veterinarians, has been described. It was shown that there were two major disease conditions contributing to deaths ascribed to "toxaemic jaundice", namely, chronic copper poisoning in which jaundice is of the haemolytic type, due to abnormal destruction of red blood corpuscles, and heliotrope poisoning following ingestion of the hepatotoxic plant, *Heliotropium europaeum*, in which jaundice results from liver damage. Problems associated with each condition are complex and, in some respects, closely related.

(i) *Chronic Copper Poisoning.*—Experiments in the field and in the laboratory have been continued. In the field experiments, attempts have continued to establish pastures which can be expected to cause the disease in grazing sheep and so provide cases developing under conditions similar to those on affected properties. Subterranean clover has been the plant of choice and the aim was to obtain early germination and lush autumn growth. By dressings applied to plots the reaction of the soil was made more alkaline and more acid respectively, and an untreated plot remained as a control. This field work was performed at the Cobram Field Station in Victoria and, despite control of soil moisture by early irrigation and soil reaction, inability to control other climatic conditions, especially temperatures, has largely defeated the objective. Conditions did not become favorable to the production of the disease although one animal on the control plot died after developing the characteristic haemolytic crisis. However, the observations made under the conditions which prevailed have added to knowledge. In another field experiment located at Tumbarumba, New South Wales, natural subterranean clover pastures were selected and top-dressed with lime and molybdenum to determine if the molybdenum intake of the sheep increased in this way would prevent the occurrence of the disease. Unfortunately, the early autumn rains did not fall; climatic conditions were therefore unfavorable for the early stocking planned. Chemical studies of the pasture, however, yielded useful information and if early autumn rains fall in 1952, the experiment will be continued.

The study of the factors influencing copper storage in the liver of sheep has been continued in laboratory experiments. Studies of the morbid anatomy of liver and other affected tissues have been continued, dietetic factors likely to influence the absorption and storage of copper in the liver are being intensively studied, and observations have been made on the relationship between the copper and molybdenum levels and partition in the blood of experimental sheep.

(ii) *Heliotrope Poisoning.*—Field studies on this disease have been centred chiefly at the Barooga Field Station, New South Wales, where experimental groups of sheep were submitted to a grazing period on heliotrope for the third year in succession. Some groups received no other special treatment, whereas others received drenches containing molybdenum or copper. The mortality rate associated with jaundice was high in some groups and the results of examination of materials collected are being collated and assessed. Members of two groups of sheep were transferred to the laboratory for more intensive study. In general, the field studies point to a high copper storage in the liver as a concomitant effect of heliotrope poisoning and in some of the experimental groups with raised copper intake the mortality rate after repeated grazings on heliotrope seemed to be significantly increased, that is, the avidity for copper is raised in sheep that have grazed on heliotrope and the animals are rendered more susceptible to chronic copper poisoning.

At the laboratory, alkaloids and their derivatives prepared by the Division of Industrial Chemistry from the plant *Heliotropium europaeum* have been placed under study in experiments with rats. At least one of these materials produced an enlargement of liver cells (megalocytosis) which is a characteristic pathological change found in natural cases of heliotrope poisoning in sheep. Other materials were lethal but produced no such change in the liver. These experiments will be further extended and continued.

(*c*) *Sheath Rot.*—Periodic observations were continued throughout the year by the Division of Animal Health and Production on a flock of 450-500 wethers in the Western District of Victoria. The seasonal variation in the incidence of both external ulceration and internal involvement of the sheath followed the same general course as in the two previous years. The preventive effect of removing the wool around the sheath of a proportion of animals, at monthly intervals from January, 1950, has been examined. The incidence of lesions was lower than that in the other animals of the flock throughout the whole period, but not much lower. Opportunity was taken to collect material for pathological examination from affected sheep sent for slaughter. The earlier assumption of workers on this disease was that it was of infective origin. There is evidence to suggest that this may not be correct.

(*d*) *Fleece Rot and Mycotic Dermatitis.*—Further studies of the predisposing factors to fleece rot in sheep were carried out at the McMaster Field Station during the continuing wet weather in 1950 and 1951. The conception that certain strains of sheep are predisposed has received further support. The association with certain strains of sheep is closer than that with any particular character of the fleece or of the sheep's conformation. As opportunity offers by virtue of the climatic conditions prevailing, hereditary predisposition will be investigated.

Investigation of a mortality in very young lambs in the Dubbo district of New South Wales showed that they were extensively affected with mycotic dermatitis. Most of the body surface was involved and had become relatively rigid, making movement difficult and painful for the animal. The outbreak was associated with prolonged wet weather.

(*e*) *Abortion in Ewes.*—A form of abortion in ewes which occurs so late in pregnancy that the lamb usually appears to be born dead at full term has been recognized for several years. Material for microbiological study has been difficult to obtain. However, during the year material became available in the New England District of New South Wales. Rickettsia-like micro-organisms were found in stained sections. Plans were made to carry out an intensive investigation should the disease recur in the flock.

16. Internal Parasites.

(*a*) *Studies on Anthelmintics.*—Further work has confirmed the need for larger doses of phenothiazine than those usually prescribed if heavy infestations of *Trichostrongylus* spp. are to be treated effectively. "Micronized" phenothiazine appeared to be more effective against *Trichostrongylus* spp. than ordinary commercial grades of the drug, but further study of the effect of particle size is required.

Under some conditions, which are not yet understood, phenothiazine treatment appears to retard live-weight increase in young sheep for a time. This was confirmed in a small trial with worm-free sheep. However, this effect, when it does occur, is likely to be more than offset by the benefit derived from removal of worm infestation. A trial was carried out in the field on a property where some adverse effects of treatment with phenothiazine were said to have occurred. No toxic effects were observed in a group of worm-infested weaners which was dosed on three occasions with phenothiazine, and a greater gain in body weight was made than in an untreated control group.

An outbreak of photosensitization in young lambs, following drenching with phenothiazine, was seen in Tasmania, with officers of that State. This is the first occasion on which the condition has been observed after phenothiazine treatment of sheep, although it has occurred fairly commonly in calves and to a lesser extent in pigs.

Several compounds which have shown toxic effects against bacteria, fungi, insects, or protozoa were tested for possible anthelmintic effects in sheep. The tests, necessarily limited in nature, gave no indication of anthelmintic effect so far as the following were concerned: pentamidine, stilbamidine, ethyl-N-phenylcarbamate, tetrachloro-*p*-benzoquinone, 2,3-dichloronaphthoquinone, copper-8-hydroxyquinolinate, 8-hydroxyquinoline, bis(5-chloro-2-hydroxyphenyl) methane, phenyl mercuric oleate, bismuth fluoride, strontium chromate, 2,2′-dipyridyl, 2-hydroxydiphenyl carbamate, selenodiphenylamine, and phenyl mercuric phthalate.

Zinc arsenate, and carbon bisulphide absorbed on bentonite, were effective against *Haemonchus contortus* when injected into the rumen but results with carbon bisulphide/bentonite were extremely variable. Hexachlorophene showed some anthelmintic effect and larger doses will be tested. A mixture of tetrachlorethylene and carbon tetrachloride appeared to have no advantage over carbon tetrachloride alone for the treatment of haemonchosis. Iodine, which has some effect upon *H. contortus* when injected into the abomasum, was ineffective when larger doses were injected into the rumen. Small daily doses of phenothiazine reduce or prevent egg production by female *H. contortus* which then appear to feed less actively.

(*b*) *Studies on Resistance to Nematode Infestation.*—Sheep which had previously been infested with *Oesophagostomum columbianum* resisted doses of larvae which were fatal to previously uninfested sheep.

Examination of records from over 100 sheep showed that "self-cure" seldom occurs in sheep which are dosed with larvae while experiencing their initial infestation with *H. contortus*. It is commonly evoked by subsequent doses of larvae but there are many anomalies which require elucidation. In addition to examining the nature of the "self-cure" phenomenon, its epidemiological implications are under consideration. For example, it now appears likely that the occurrence of outbreaks of haemonchosis is not determined solely by the numbers of infective larvae ingested, but also by the periodicity of the sheep's previous exposures to infestation.

Further observations have been made on the effect of plane of nutrition upon susceptibility to trichostrongylosis. Weaners on rations which resulted in live-weight increases of 21 lb. and 33 lb. in five months developed much lighter infestations with *Trichostrongylus* spp. after a given dose of infective larvae than similar sheep kept on a plane of nutrition which was merely sufficient to prevent loss of body weight and which received the same number of larvae. These sheep were about one year old when the trial commenced and were carrying 6 months' wool. When shorn, six months later, those on the low plane of nutrition cut 7 lb. and those on the highest plane 12 lb. of wool. Another somewhat similar trial, now in progress with younger sheep, appears to be giving similar results. These trials, and others which have preceded them, indicate that sheep on a high plane of nutrition can cope with relatively heavy infestations with *Trichostrongylus* spp. and that there is a closer and clearer relationship between nutrition and resistance to these species than there is in haemonchosis. It is often difficult to see this relationship

clearly under field conditions because of interacting circumstances. For example, in field trials conducted in the Yass district during the year, worm infestation increased appreciably during the abnormally dry summer apparently as a result of infestations acquired during the wet spring months. Nutritional conditions for the sheep were poor and malnutrition caused fairly heavy losses.

Serological studies on resistance and immunity to helminth infestations of sheep have been continued and are breaking new ground. No evidence has been obtained that resistance to *Haemonchus contortus* is the result of acquired immunity. The vigour of the antibody response to administration of *H. contortus* larvae does not reflect the sheep's ability to resist the infestation and circulating antibody, detectable by the complement-fixation test, quickly wanes. Moreover, a sheep may resist one or more infestations only to prove fully susceptible to a subsequent dose of larvae.

The facts are quite otherwise as regards resistance to *Trichostrongylus* spp. In sheep which survive this infestation, there is a strong and sustained antibody response. The fact that sheep two years of age or older are very seldom affected with trichostrongylosis is not due to "age resistance" as was previously thought, but to acquired immunity. Sheep under a year old rapidly acquire immunity to *Trichostrongylus* spp., but worm-free sheep are still fully susceptible at 3½-4 years of age. Considering the 158 sheep which have been studied serologically in connexion with experimental infestation with *Trichostrongylus* spp., the behaviour of 132 of them supported the view that the level of circulating antibody is a reflection of the degree of immunity and that of the remaining 26 sheep was anomalous. This difference is highly significant statistically.

An interesting observation, and one which may have certain practical applications, was that when the serum titre of sheep infested with *Trichostrongylus* spp. declines, eggs of these species may appear in the faeces, even after a long series of negative or near negative counts. In these sheep the worms have persisted in the small gut for three or four months without producing eggs and without clinical effect upon the host, yet when the serum titre declined, the infestation developed and in some cases proved fatal. In one sheep the serum titre remained high for thirteen weeks and during the last six weeks of this period faecal egg counts were negative. The animal was then slaughtered and over 5000 mature *Trichostrongylus* spp. were found in its small intestine.

Although sheep on a very low plane of nutrition are more susceptible to infestation with *Trichostrongylus* spp., the low diets did not appear seriously to weaken an immunity which had resulted from previous infestations.

Sheep which have been reared free of worms and in which a good level of circulating antibody to *Trichostrongylus* spp. has been induced are, nevertheless, still fully susceptible to *Haemonchus contortus* and the serum titre is not increased by administration of *H. contortus* larvae. Hence, although sera which are positive to the complement-fixation test as a result of infestation with *H. contortus* or with *Trichostrongylus* spp. cross-react, the stimuli to the formation of circulating antibodies to the two species must be quite distinct.

The "self-cure" phenomenon has been further studied. More closely spaced serological and faecal examinations have shown that the rise in serum titre either coincides with, or quickly follows, the fall in faecal egg count. When the decline in egg count is transient, so is the rise in serum titre. That the rise in serum titre, associated with "self-cure", is not due to a general release of antibody, was shown by inducing the phenomenon in sheep with circulating "H" and "O" agglutinins to *S. typhi-murium*. No increase occurred in the titre of these agglutinins. The "self-cure" phenomenon now appears to be due to an allergic type of reaction in sheep which have been sensitized by previous infestation. It is characterized not only by a transitory rise in circulating antibodies to *Haemonchus contortus* but also by a still more transitory increase in blood histamine. Of fourteen sheep which manifested "self-cure" seven showed increases in blood histamine from 0.1-0.2γ to 0.5-0.7γ per ml. Of thirteen sheep which did not manifest "self-cure", none showed any increase in blood histamine. The rise in blood histamine may occur on any day from the second to the fifth after administration of larvae and is present on only one day, so that it is easily missed unless very frequent blood samples are taken over a period of some days. The reactive substance was characterized as histamine by the use of "Anthisan". This work is proceeding.

(*c*) *Epidemiological Investigations.*—At the McMaster Field Station, attempts have been made to study the population dynamics of helminth infestation by recording the rates of development of infestations in small groups of sheep with initial infestations of different degrees. In one trial three lots of four sheep with initial average worm-egg counts of 6,300, 1,450, and 575 per gram of faeces were run in small separate paddocks. During the next four months heavy infestations developed among the sheep with the initial infestations of 6,300 and 1,450, but not among those with the lightest initial infestation. When this trial began the contamination rates for the three paddocks were approximately 25, 6, and 2.5 million worm eggs per day. At the lowest rate of contamination it appeared that the parasites did not readily build up a heavy infestation. Further trials of this nature are required but the results so far serve to emphasize the necessity for maintaining worm burdens at low levels if outbreaks are to be avoided. If the contamination rate is allowed to rise above a certain level the risks of an outbreak may be greatly increased.

With the co-operation of the Department of Agriculture, epidemiological studies began in Tasmania in January, 1951, and have already provided useful information on seasonal changes in the worm burden of sheep. Special studies were carried out at "Frodsley" during 1950-51 and are being continued. The worm burdens of lambs in that region of Tasmania increased rapidly from November to early January and then decreased. It appears that lambs may suffer ill effects from helminthiasis for some time before weaning. In another trial a flock of weaners on the east coast developed heavy infestations with some deaths early in March, about two months after weaning.

In the course of the work, a comparison was made of the levels of worm infestation in lambs from ewes milking well and from ewes which had dried off or were producing only small amounts of milk. The comparison was made early in January when the lambs were about four to five months old. The lambs from ewes still milking well had average weights of 54.6 lb. and average worm-egg counts of 1,430 eggs per gram of faeces, whereas the corresponding figures for lambs from ewes which were either "dry" or not milking well were 48.9 lb. and 1,940 eggs per gram. It appears that much of the subsequent unthriftiness in young sheep may have its genesis in the poor milk supply of the ewes and that lambs which do not receive an adequate milk intake form the "tail" of the flock and constitute the major problem in the control of helminthiasis.

It is proposed to begin epidemiological studies in Western Australia in the spring of 1951. Examination of a number of sheep there in September, 1950, showed that heavy infestations with *Haemonchus contortus*, *Trichostrongylus* spp., and *Chabertia ovina* may be

already established by the end of August and probably even earlier in the winter. Preventive treatment of lambs and weaners will be required during winter months, but it may be difficult to make precise recommendations for the timing of preventive treatments until records of monthly changes in worm burdens have been recorded for at least a year.

(*d*) *Parasite Physiology and Toxicology.*—(i) *The Mode of Action of Phenothiazine as an Anthelmintic.*—It was considered possible that phenothiazine was modified in the gastro-intestinal tract of dosed animals and that its anthelmintic effect was due to the modification or to some derivative of phenothiazine. The nature of phenothiazine derivatives in the gut contents and in the tissues of parasites poisoned by the drug was, therefore, examined. The compounds were extracted with benzene in an atmosphere of nitrogen and then examined by paper chromatography. Materials on chromatograms were examined by taking autoradiographs or by counting, when 35S- labelled phenothiazine was used, or by spectrophotometry. It appears that phenothiazine in the gut contents and in the tissues of poisoned parasites forms some complex, possibly with fatty material. So far as the work has gone, no other compound of phenothiazine has been detected. The rate of penetration of the phenothiazine complex from gut contents into parasites is similar to that of unchanged phenothiazine. Of the phenothiazine in poisoned parasites, 68 per cent. was associated with alcohol-soluble material and 10 per cent. with acid-soluble material.

The anthelmintic activity of compounds similar to phenothiazine is also being investigated. The compounds are being prepared by the Organic Chemistry Department of the University of Sydney and are being compared at the McMaster Laboratory with highly purified phenothiazine in their effect upon a small nematode parasite in mice (*Syphasia* spp.). From a study of these compounds it appears that the —S— and —NH— in the central ring of phenothiazine are essential for high activity although in some compounds anthelmintic activity is obtained when the —NH— is replaced by —S— or simply removed. The investigation is being extended to determine the activity of phenothiazine compounds in which the phenol groups are modified or increased in number.

(ii) *The Uptake of Phosphate by Nematode Parasites of the Small Intestine of Sheep.*—This investigation was undertaken to obtain more information on the feeding habits of the parasites and thus, if possible, to discover how the parasites take up phenothiazine from the gut of dosed animals. The results may be summarized as follows: the rate of uptake of labelled phosphate by *Haemonchus contortus* was similar to that of the host's tissues; after intravenous injection *Trichostrongylus* spp. accumulated phosphate at a rate which paralleled that at which phosphate accumulated in the intestine mucosa; up to four hours after dosing, *Oesophagostomum columbianum* took up less than the tissues of the host's colon, but thereafter showed a rise which was somewhat variable. These results suggest that the parasites feed on the tissues of the host and not on the contents of the alimentary tract.

(iii) *Nitrogen Catabolism of Nematode Parasites.*—*Nematodirus* spp. and *Ascaridia galli* were maintained for 24 hours in a non-nutrient medium in which bacterial growth was prevented by the incorporation of penicillin and streptomycin. The nature and quantity of nitrogenous excretory products were determined. Peptides and ammonia formed the bulk of the excreted nitrogen; some urea and uric acid were produced by *Nematodirus* spp. and some urea but no uric acid by *Ascaridia*. Experiments with tissue preparations from the parasites showed that urease was present and that urea was produced by some form of the ornithine cycle. The intestine of the parasites was the most active of the tissues in respect to arginase and urease. The breakdown of purines, which was most active in young adult *A. galli*, probably took place via uricase, allantoinase, allantoicase, and urease.

The peptide fraction of the nitrogenous excreta of the parasites is being examined further because it may contain toxic or antigenic properties.

(iv) *Studies on the Nucleic-acid Metabolism of the Malarial Parasite* Plasmodium berghei.—Determination of the nature and amount of nucleic acid in these parasites has proved difficult because the white blood cells, which contain nucleic acid, increase greatly in the blood of infected animals and it is very difficult to separate them from the parasitized cells. Estimation in which allowance was made for the nucleic acid in the white cells indicated that the parasites contained 223 times the amount of ribonucleic acid and 3–5 times the amount of desoxy-ribonucleic acid which are found in unparasitized red blood cells. Methods for examination of the purines and pyrimidines in the nucleic acid of the parasites are being developed. It has been found that *P. berghei* in otherwise sterile cultures produces haemolysins which rapidly haemolyse the red cells in the medium.

17. External Parasites.

(*a*) *Control of Body-louse* (Bosicola ovis) *among Sheep in Long Wool.*—Under some conditions, treatment of louse-infested sheep by orthodox methods may be undesirable. The dipping of sheep in long wool tends to cause staining of the fleece and so to reduce its sale value. Preliminary tests in the laboratory showed that louse infestations in sheep carrying several months' growth of fleece could be greatly reduced by jetting BHC preparations into the fleece in small quantities and under relatively high pressure. Quantities used ranged from 1.5 to 3 pints per sheep and the concentration of gamma-BHC ranged from 0.007 to 0.01 per cent. The use of 1.5 pints of 0.007 per cent. gamma-BHC gave the least satisfactory results. In a subsequent trial under field conditions, 65 infested sheep carrying 8 months' wool were treated with 0.035 and 0.07 per cent. gamma-BHC at the rate of 0.45–0.8 gallon per head. This treatment reduced the infestation sufficiently to prevent further damage to the fleeces by rubbing and biting. The method involves the forceful injection of the insecticide beneath the surface of the fleece so that little if any dirt is carried into it from the tip of the staple.

(*b*) *The Use of Insecticidal Fogs for Control of Ectoparasites of Sheep.*—Two further trials have been carried out during the year. In the first of these, 22 lambs and 50 ewes infested with keds, and 35 wethers infested with lice, were fogged immediately off shears with 2.0 per cent. gamma-BHC in diesel-distillate mixture. Five weeks later, 6 out of 15 wethers examined were still infested with lice but two keds were found on only one of the 50 ewes and none on the 22 lambs. Thus, under these conditions, lice were not controlled but the result with keds was encouraging and justifies further trials with different concentrations and times of exposure. In the second trial, 46 louse-infested sheep were specially shorn so that some were deliberately left with patches of longer wool. Lice were not eradicated and were found more frequently in the longer wool. Further investigation of the use of insecticidal fogs for control of lice and keds are justified but few properties have adequate facilities for isolation of the treated and control sheep after treatment, which is necessary for experimental investigation.

18. Sheep Blowfly.

(*a*) *Protection against Body Strike.*—(i) *Field Trials.*—Several field trials were undertaken in the Merriwa, Willow Tree, Coolah, Binnaway, and Mudgee districts of New South Wales. They were designed to give further information on the relative value of DDT and BHC for prevention of body strike, the period for which they would afford protection, the most effective and economical concentration and quantities, and the merits of different methods of application, such as jetting, power-spraying, and the use of insecticidal fogs and mists. Some 8,000 sheep were used in these trials, some of which were commenced in November and treatments repeated at intervals until the onset of colder weather precluded any likelihood of a fly wave. Unfortunately, under the prevailing seasonal conditions blowflies were relatively inactive during the summer and autumn and this large volume of time-consuming work gave no conclusive results. In one trial there was a mild wave of fly strike approximately 8 weeks after the sheep had been jetted with 0.5 and 1.0 per cent. DDT, and 0.05 and 0.025 per cent. gamma-BHC. One quart of the insecticidal preparation was applied to each sheep, from the poll to the rump. Although previous field observations had suggested that such a treatment would protect for only about 4–6 weeks, it was apparent in this trial that even after 8 weeks a valuable measure of protection remained. Untreated control sheep incurred 16.6 per cent. of body strikes, whereas the incidence in the treated groups ranged from 4.6 to 10.2 per cent. The opportunity was taken to collect fleece samples from sheep at intervals after various treatments. These are being analysed to determine the quantities of insecticide deposited and the rate at which it is dissipated.

Further trials with DDT and BHC were carried out in Queensland during the spring of 1950 and the autumn of 1951, but body strike failed to occur in either the treated or the control groups.

As a treatment for body strike, 0.05 per cent. gamma-BHC (8 times the strength for dipping) proved only reasonably efficient and the use of 0.1 per cent. seems to be justified. One per cent. *pp'*-DDT was found to have no larvicidal action and proved unsuitable for the treatment of struck sheep.

(ii) *Extension of Period of Protection.*—Field trials have shown the value of spraying sheep along the back with DDT and BHC as a protection against body strike. Commercial preparations of these toxicants afford protective periods of 1–2½ months. It would be advantageous to extend the period of protection to even greater periods, so a test has been commenced by the Division of Entomology in which DDT has been substituted for the pigment in L.B.E. branding fluid base. This branding fluid base retains the pigment on the fleece for a year and hence should also minimize mechanical removal of toxicants. By means of insectary tests the susceptibility of the sheep to strike will be compared periodically with that of sheep treated with a colloidal preparation.

(*b*) *Lamb-marking Dressings.*—A comparison was made by the Division of Animal Health and Production between a boracic-bentonite-citronella ("Borocit") and a boracic-bentonite-dibutyl phthalate lamb-marking dressing. Although the dressing incorporating the dibutyl phthalate gave promising results when applied at the rate of one gallon of dressing per 67 sheep, it was definitely inferior to the "Borocit" dressing when the rate of application exceeded 100 sheep per gallon.

(*c*) *Application of Dressings to Unshorn Strikes.*—Small-scale tests by the Division of Entomology with commercial preparations of BHC at a concentration of 0.1 per cent. gamma isomer, and of DDT at 2 per cent. *pp'*-DDT showed that when these fluids were liberally applied to unshorn strikes and rubbed into the fleece the progress of the strike was quickly arrested, healing was satisfactory, and there was no restrike. The method appears to be suitable for the treatment of small strikes and the temporary treatment of large strikes.

19. Other Investigations.

(*a*) *Neo-natal Mortality in Lambs.*—These studies were continued at "Chiswick" Field Station during the year. Heavy and continuous rain during the lambing period was the chief cause of losses of lambs in the station flocks. Losses were higher than in the previous years and ranged from 16 to 38 per cent. in the ewes which lambed in the several groups.

Detailed observations were made of losses in the strain trial (Merino) and Romney Marsh flocks which were lambed under pen conditions. A temporary shelter shed was available during inclement weather for ewes with young lambs, and this reduced losses. All the 23 Romney Marsh lambs born survived to marking time, but 70 out of 355 strain trial lambs died before marking. The heaviest losses were in the fine-wool and Peppin medium-wool groups. The more important causes of losses were: poor mothering ability of ewes, with or without poor milk supply, stillbirths, lambs of poor birth vigour, and inclement weather. During the course of lambing there appeared to be a rising gradient with respect to maternal instinct, milk supply, and lamb vigour from the fine wools through the medium and then strong wools to the Romney Marsh. This was confirmed to some extent by the incidence of lambing mortality in the several groups.

A possible cause of loss of lambs from ewes "lambed in the wool" is the presence of long wool and sweat dags about the flanks and udder. These may interfere with the ability of a weak lamb to obtain milk. In 1949 and again in 1950, a trial was carried out in which the effect of removal of these impedimenta was examined by treating three groups of ewes as follows: (i) normal crutch, i.e. removal of wool on posterior portion of udder and crutch area, (ii) normal crutch plus removal of the wool on the lower edge of the flanks and 3-4 in. anterior to the udder, and (iii) normal crutch plus removal of all belly wool. The results, based on the number of lambs lost between birth and marking, tend to favour the more drastic forms of crutching, but the reduction in losses has not been great.

Entero-toxaemia was excluded as a cause of pre-marking losses of lambs in the flocks.

An extension into the third year of records of lambing data for a group of ewes originally mated as maidens in 1948 has confirmed the finding of the 1949 mating, that ewes which reared a lamb to marking as maidens had a better record of lambs reared in the succeeding years than ewes which either lost their lambs or failed to lamb as maidens.

Experiments on the effect of stilboestrol implants in pregnant ewes were carried out during the year. Implants consisting of ten 5-mg. tablets (50 mg.) were made in nine ewes 98-111 days pregnant. After two days, all nine ewes had increased udder development compared with a control group of twelve ewes in a similar stage of pregnancy, and eight had produced a milk-like secretion. The treated ewes displayed inappetence and listlessness for seven to ten days after treatment. One ewe aborted thirteen days after treatment and one control ewe also aborted at about the same time. The remaining eleven controls lambed normally and the mean body weights of their lambs were 7.7 lb. for the males and 7.5 lb. for the females. In the treated group, only one ewe lambed normally. The remaining seven had dead lambs, none of which

were delivered unaided although the foetuses were carried to term. At no time were any of the seven observed in labour. Four of the ewes were delivered by hand of dead emphysematous lambs, two ewes died, both with dead lambs *in utero,* and the remaining ewe retained the foetus although it appeared reasonably normal six to seven weeks after the due date of lambing. One of the dead foetuses weighed 4 lb., whereas the remainder ranged from 5 to 5.7 lb. All had the appearance of a premature foetus.

At "Gilruth Plains" every lamb which died, among some hundreds which were born in lambing yards, was subjected to a careful postmortem examination and bacteriological examination of tissues was made. No evidence of any infectious disease was found.

(*b*) *Factors Influencing Birth Weight and Rate of Growth from Birth to Weaning.*—Following the discovery that at several centres the mean birth weight of lambs failing to survive was lower than those which lived, the factors influencing birth weight and the association between birth weight and subsequent performance of the lamb have been investigated. In conducting the statistical analysis for this investigation, interesting results have been obtained by the Section of Mathematical Statistics.

Data for four years were used, and the analysis demonstrated that birth weight increased with age of dam up to six to seven years, and also with length of gestation period, the gain for male lambs averaging 0.13 lb. per day, and for female lambs ranging from —0.06 to 0.23 lb. per day. With the latter, a strong and consistent association occurred between respective size of dam and progeny, the increase averaging 0.2 lb. of birth weight per 100 increase in the size index of the ewe (approximately 5 lb. in live weight), whereas for ram lambs the corresponding figure was 0.07 lb. per 100 increase.

It was found that lambing date within the lambing period had no consistent effect on birth weight for either sex. There was a difference between the sexes, however, in gain per day from birth to weaning. For male lambs the regression coefficient for size of dam, though very small, was consistently positive, but for female lambs birth weight had a marked influence, gain per day increasing on the average by 0.01 lb. for every increase of 1 lb. in birth weight. For female lambs, also, the slight negative association between length of gestation period and gain per day would be consistent with an assumption that rate of gain *in utero* was correlated with rate of post-natal gain. Of two animals having equal birth weight, that with the shorter gestation period would have the greater rate of gain. Size index of dam was positively associated with rate of gain of female lambs in all four years, but the effect was slight.

(*c*) *Survey of Fine-wool Production.*—This survey, which is particularly concerned with the performance and production of Merino sheep in eastern Australia, has been continued. Work was carried out in the south-west, north, and north-west of Queensland. The exceptionally heavy rains experienced through the year considerably disorganized the programme of work as the roads became impassable, sometimes for weeks at a time. The types of country covered included gray and brown soil, mitchell grass plains, and open forest in the south-west, the black soil downs of the Clermont-Springsure area, the treeless rolling downs of the north-west, and the open forest "desert" country. The sheep throughout these areas are almost all Merinos. Approximately 90 per cent. of properties use rams of Peppin blood, and the remainder, South Australian. Although in parts fine to superfine wool is produced, as far as could be learned there has been little or no introduction of Tasmanian or table-land type rams during the last 30 years. Although in the main the area traversed is used for breeding, it is usual to retain wethers for a number of years and there are some relatively small areas which are given over entirely to dry sheep. Marking percentages in the northern part of the State are uniformly low, averaging 50 per cent. or less throughout. One of the major problems facing many parts of the northern sheep-raising areas to-day is the depredation of dingoes. Owing to shortages of netting and of reliable labour, dingoes have increased in numbers and in many places have been the cause of properties changing from sheep to cattle. As the owners of cattle are not seriously concerned about them this has led to deeper penetration into the sheep country, thus accentuating the trouble.

The sheep blowfly is still a serious problem throughout the area. Although the Mules' operation is fairly widely practised, there are still a large proportion of graziers who through apathy or prejudice have not adopted it. During the year, however, the principal trouble was body strike, associated with the abnormally wet conditions. One of the chief difficulties in dealing with this outbreak was that, for extensive periods when the fly wave was at its worst, it was impossible, on account of the state of the ground, even to muster the sheep, let alone to carry out treatments. DDT and BHC were reported to have been used to good effect on several places.

(*d*) *Subnormal Growth and Development of Young Sheep.*—This problem was investigated in Tasmania in collaboration with officers of the Department of Agriculture. The object was to determine why, under some apparently good conditions, lambs at foot on highly improved pasture do not develop satisfactorily, and a large proportion of the weaners are unthrifty. The investigation excluded a low intake of cobalt and copper as being associated with the malnutrition. A low milk production in the ewes showed a close correlation with malnutrition in the lambs. The investigation is proceeding.

(*e*) *The Effect of Grazing Management on Pasture and Animal Production.*—A co-operative investigation is being carried out with the Division of Plant Industry (*see* Chapter III., Section 13 (*a*)) in which a study is being made of the effect of different rates of stocking, rotational grazing, and grazing with different sizes of flock on the health and production of the grazing sheep and of the pasture.

In a comparison of stocking rates of one sheep to 1 acre, ¾ acre, and 1¼ acres, the trend towards higher sheep body weights on the lighter rate of stocking recorded in the first two years of the trial has been continued into the third year but is somewhat less marked. Parasitism reached high levels in the summer and autumn of 1951. Differences between groups of sheep in the level of parasitism were recorded, but do not appear to be related to the rate of stocking treatments. Analyses of all the data are not yet complete.

Continuous grazing has resulted in slightly greater body weights than rotational grazing at the same rate of stocking, although the differences have been slight. During the summer and autumn of 1951, the rotational grazing system practised (grazing for one week in four) was not effective in preventing the build-up of heavy and in some cases pathogenic worm populations in the grazing sheep.

Results from the first year of an experiment in which sheep are grazed in flocks of 2, 4, 8, 16, and 30 have shown consistently lower body weights with a flock size of two. This difference is probably due to a difference in grazing behaviour. It has also been shown that small flock size does not preclude a build-up in parasitism.

VIII. CATTLE.

1. General.

The Organization's work on dairy and beef cattle problems is being carried out within the Division of Animal Health and Production (mainly centred at the Animal Health Laboratory, Melbourne, and at the Veterinary Parasitology Laboratory, Brisbane) and is described in Sections 2, 3, 5, and 6 below.

The Division of Entomology has been concerned with work on the cattle tick, an outline of which is given in Section 4. The work of the Division of Plant Industry on pastures (*see* Chapter III., Sections 9-17) is also of importance to the cattle industry.

2. Cattle Diseases.

(*a*) *Pleuropneumonia of Cattle.*—This is the most serious infectious disease affecting beef cattle in the northern areas of Australia with the exception of tick-borne diseases. Unlike the latter, it constitutes a constant menace to the beef and dairy cattle in the south because of the risk of spread through the agency of infected "carrier" cattle, which are apparently healthy. Methods elaborated by the Division of Animal Health and Production for the diagnosis of infection in "carrier" cattle and for the protection of healthy herds by vaccination are extensively used. In the current year, 813,000 doses of vaccine were prepared and forwarded to distributing centres in Queensland, the Northern Territory, New South Wales, and South Australia, almost double the amount for the previous year. Large amounts of antigen for use in the diagnostic complement-fixation test were again provided cost-free to government authorities in several Australian States and in Kenya and Nigeria. An officer was seconded for a period of two months for service with the Animal Industry Division, Northern Territory, where useful field data were collected.

Periodical testing of the protective power of vaccine involves considerable expenditure of time and money. In a recent test, extending over six months, 30 head of three-year-old dairy cows were vaccinated and the immunity of these and of 15 unvaccinated control cattle was subsequently challenged by the introduction of a mist of virulent organisms into the respiratory tract. The challenging strain was one of exceptionally high virulence and, although 90 per cent. of vaccinated animals were fully protected, 10 per cent. showed slight lesions in the lungs. The usual proportion of cattle protected against several other virulent challenging strains has been greater than 99 per cent. New tests are planned to study the virulence of this new strain.

The Section of Microbiological Chemistry began during the year an intensive study of the metabolism and nutrition of the causal organism of this disease.

(*b*) *Tuberculosis of Cattle.*—Effective measures for the eradication or control of bovine tuberculosis depend, chiefly, upon the accuracy of tuberculin tests used for diagnosis of the disease. Testing authorities throughout the world have greatly reduced the incidence of tuberculosis in herds by the use of the intradermal tuberculin test. However, in Australia and elsewhere, difficulties arise in some herds under test because tubercle bacilli of the human type or related organisms in the environment which have temporarily gained entrance to the tissues produce "false positive" reactions in healthy cattle; furthermore, cattle extensively affected with tuberculosis sometimes fail to react. Consequently, there is a need for tests which are even more specific.

In previous reports, a supplementary short thermal test was described which, although dependent upon the reaction of body temperature to subcutaneous injection of tuberculin, was found to be practicable and was recommended for use in "problem" herds and suspected chronic cases. During the year reports from the field indicated that it has been applied by statutory testing authorities in several States with good results.

In the laboratory, work was restricted to the study of a new diagnostic test on blood serum, in collaboration with an officer of the Commonwealth Serum Laboratories. It was based on the lysis of sheep red blood corpuscles coated with a fraction extracted from tubercle bacilli. In the presence of serum from the majority of tuberculous cattle and of a specially added factor (complement), these cells disintegrate. This serological test proved to be not more accurate than the tuberculin test applied in the field but there is evidence that it may be usefully employed in diagnosing Johne's disease in cattle, which is caused by an organism closely related to the tubercle bacillus.

(*c*) *Mastitis in Dairy Cattle.*—For years, the Division has maintained, close to the Melbourne metropolitan area, a herd of dairy cows for the intensive study of mastitis, perhaps the most serious cause of economic loss in the dairying industry in Australia and throughout the world. During that time contributions have been made to the pool of scientific knowledge relating to the epidemiology and control of the disease. Theories regarding the mode of infection and methods for controlling the disease have been tested in commercial herds. As a result, Australian dairymen have been provided with very satisfactory means of minimizing the incidence of mastitis and of benefiting to the utmost from the correct use of new drugs and antibiotics which have become available for treatment. It is now possible, almost, to eliminate infection from a herd by the application of recommended measures. With this reduction of the streptococcal infection the staphylococcal form, less serious economically, has become more apparent.

In the experimental herd at Werribee, Victoria, streptococcal mastitis is at present virtually absent as a result of adequate shed hygiene without the application of intensive treatment. In this herd, and elsewhere, methods of treating staphylococcal mastitis have been tested. Penicillin, so effective for treatment of the streptococcal form, has been administered in large doses intravenously, subcutaneously, and by udder infusion, but results have not been encouraging. Aureomycin shows greater promise but udder infusion, in a dosage claimed to be effective by investigators in the U.S.A., has not proved completely satisfactory. Additional supplies have been obtained and further trials planned. Supplies of the antibiotic, nisin, claimed to have been used successfully in the United Kingdom, are not yet available.

Despite the availability of information regarding the control of streptococcal mastitis, a large proportion of Australian herds is still more or less seriously affected. Therefore, following the encouraging reports from the United Kingdom, it was decided to investigate the practicability of eliminating the causal organism, *Str. agalactiae*, from some infected herds by the simultaneous treatment of all quarters of all cows ("whole herd treatment") with penicillin and special disinfection of the environment, including external surfaces of cows' udders and teats, shed floors and fittings, milking utensils, and hands and clothing of attendants. Early results do not suggest that the same success will be achieved in the Australian environment as was achieved where different methods of animal husbandry are practised overseas. Further trials are in progress.

(*d*) *Brucellosis in Cattle.*—Previous work showed that "strain 19" vaccination offered a practicable method of controlling brucellosis (contagious abortion) in cattle in Australia and its widespread use in recent years has greatly reduced the incidence of the disease in many herds.

In attempting to improve the protection following vaccination, new methods of vaccination have been tested. Preliminary experiments with adult cattle showed that a higher level of antibody resulted from injection of 1.0 ml. into the tip of the tail (intracaudal vaccination) than from the universally practised method of injection of 5.0 ml. under the skin (subcutaneous vaccination). English workers tested the implication of the C.S.I.R.O. work, namely, that equal or greater protection might result from tail vaccination, and found it to be true for heifers vaccinated at the age of fifteen to eighteen months. As "strain 19" vaccination in Australia is practised almost exclusively on calves, field experiments were commenced at the end of 1948 to compare the effects of intracaudal and subcutaneous vaccination of calves at the age of seven to ten months and two sections of this work have now been completed.

In the first section, dealing with the resultant level of antibody agglutinin in the blood serum, results showed (i) that a higher average level was attained in calves vaccinated when older (nine to ten months) than when younger (seven to eight months), (ii) that in all calves (seven to ten months) tail vaccination gave an average level almost twice as great as subcutaneous vaccination, and (iii) that vaccination at the older age of nine to ten months left higher agglutinin levels at the age of breeding, twelve months after vaccination, than did vaccination at the younger age of seven to eight months. High residual levels at that period affect the accuracy of routine blood tests for contagious abortion and are, therefore, considered undesirable.

In the second completed section, dealing with resistance to abortion and infection in the second year after vaccination and during the first pregnancy, it was clearly shown (i) that "strain 19" vaccination provided a serviceable but not complete protection to both vaccinated groups, and (ii) that the intracaudal method of vaccination provided protection as good as or slightly better than the subcutaneous method. Under Australian conditions, where the difficulties of packing vaccine for transport over great distances and of storage at a low temperature are of great practical and economic importance, reduction of the effective vaccinating dose to one-fifth should prove of practical value.

The experiments are being continued in order to test immunity in the third year following vaccination and during a second pregnancy. Much useful material for laboratory work has been available and a new diagnostic test on milk obtained from heifers soon after parturition has been evolved which is likely to prove of practical value in the field. It is more accurate than the "ring test" described by overseas workers and less complicated than the whey agglutination test. As with other tests for the diagnosis of brucellosis, the extent to which false positive reactions occur after "strain 19" vaccination has yet to be assessed.

(*e*) *Haematuria vesicalis.*—This disease, which has a world-wide distribution in limited areas, causes death from continuous haemorrhage into the urinary bladder, and in Australia and elsewhere intensive field and laboratory studies have failed to reveal the cause. Current work in the Division is based on the hypothesis that the bladder lesions result from the presence of irritant substances in the urine. A study is being made of the aromatic amines and aminophenols in the urine. For this purpose it has been necessary to devote a considerable proportion of the available time to the slow and laborious synthesis of reference compounds.

(*f*) *Anaplasma centrale.*—A strain of *A. centrale* was kept in a viable condition for at least 739 days at −80° C. The strain is maintained at this temperature and is passaged through calves from time to time. During the year a sample of it was forwarded to the Animal Health Station, Queensland, to replace the old strain maintained there.

3. Internal Parasites.

(*a*) *Epidemiology of Parasitic "Gastro-enteritis" of Cattle.*—These studies have been continued. Herds at Maleny, Dayboro, Oakey, Queensland, and Armidale, New South Wales, are under observation. The Maleny trials are directed mainly at the value of pasture rotation as a control measure. The herds from the Darling Downs (Oakey) have yielded some interesting information on the distribution of some of the species of helminths. In this district, which has an elevation of 1,500-2,000 feet, *Bunostomum phlebotomum* has not been seen and *Cooperia oncophora* and *Nematodirus* sp. are common and abundant, whereas only 80 miles away on the coast, *B.phlebotomum* has a high incidence, *C. oncophora* is unknown, and *Nematodirus* sp. is rare. Otherwise there is little to add to the information given in the 1949-50 Annual Report.

Extremely high egg counts of *Cooperia punctata* and *C. pectinata* have been encountered in dairy calves from time to time and in one herd these reached 20,000-37,000 eggs per gram.

Eggs of *Ascaris vitulorum* were seen in calves from Armidale, New South Wales, and from Dayboro, Queensland. This is the first time eggs of this species have been seen in these studies. The cattle ascarid has not previously been reported from Australia.

(*b*) *Faecal Examination as a Measure of Helminth Infestation in Cattle.*—The work during the year has been concerned mainly with daily faecal output in relation to growth of the host, in order to obtain a factor for the comparison of the egg output of young and adult animals as a measure of helminth infestation. A large series of faecal output figures has been obtained from animals, including identical twins, held under controlled conditions, and the figures are being carefully analysed.

(*c*) *Fasciola hepatica.*—Results of a survey to determine the distribution of *F. hepatica* in Queensland have been obtained. Apart from an area of infestation in the southern Darling Downs, where sheep are mainly concerned, the fluke appears to be confined to the Mary Valley, where the incidence in cattle has been as high as 50 per cent. on some properties. An isolated case of infestation in cattle from Spring Creek, near Georgetown, which is towards the south of the Cape York Peninsula, has been reported.

At the invitation of the Department of Agriculture of South Australia, a visit was made to the fluke-infested areas of that State. Heavy losses among sheep occur mainly in the districts around Lakes Alexandrina and Albert. These lakes at the mouth of the Murray River were originally salt but the construction of barrages at the mouth of the river has resulted in the water remaining fresh and favorable to the establishment of large populations of the snail intermediate host. No practicable method of improving the effectiveness of the present control measures could be devised, but in view of the possibility that permitting intermittent ingress of the sea might be a useful measure, salinity tolerance tests of the South Australian snail intermediate host were carried out. These showed that 5.8 grams NaCl per litre (400 g. per gal.) was fatal to all snails in 24 hours. At 2.29 grams NaCl per litre some snails survived for seven days. The intermediate host of *F. hepatica* in South Australia is named *Simlimnea subaquatilis.* A study of the

habits of this species and measurements of its shell and of its radula dentition could not distinguish any constant differences between it and *S. brazieri*, the intermediate host in New South Wales and Queensland. It was concluded that these names are synonymous, *S. subaquatilis* having priority. Probably *S. victoriae*, the intermediate host in Victoria, is also the same species as *S. subaquatilis*.

(*d*) *Echinococcus granulosus.*—The hydatid survey has been completed and a total of 39,242 animals were reported upon by inspectors of the Department of Agriculture and Stock, Queensland. An overall infestation figure of cattle on coastal and subcoastal areas reached 31.01 per cent., the highest incidence of 70 per cent. occurring in the Landsborough district. Several hundred cysts from cattle have been examined, of which only one was fertile. Investigations are being continued to determine whether native fauna play any part in the distribution and incidence of this parasite in cattle.

(*e*) *Amphistomes of Cattle in Queensland.*—Paramphistomiasis of cattle is limited mainly to the coastal-subcoastal areas, particularly where an annual rainfall of 30 inches or more is recorded. Infestations are heaviest in the south-eastern areas.

In the 1949-50 Annual Report, two species of amphistomes were recorded, namely *Paramphistomum cervi* and *P. cotylophorum*, the intermediate hosts being the planorbid snails *Glyptanisus gilberti* and *Segnitilia alphena* respectively. Repeated negative attempts to infect these snails in the laboratory led to a detailed study of the species of adult flukes. By the use of Nasmark's system of determination, four species were found to be present. The species previously called *P. cervi* was found to be *Calicophoron calicophorum*, and *P. cotylophorum* was found to be a complex of two species, *P. ichikawai* and *Ceylonocotyle streptocoelium*. The fourth species has not yet been determined but is closely allied to *C. calicophorum*. No specimens of *Gigantocotyle* (*Paramphistomum*) *explanatum* reported from Queensland by other workers were seen.

On the basis of these determinations little difficulty was experienced in ascertaining the life histories of *C. streptocoelium*, which uses the snail *G. gilberti*, and of *P. ichikawai* in the snail *S. alphena*. The snail intermediate host of *C. calicophorum*, the most abundant of these amphistomes, has not yet been found.

4. Cattle Tick.

(*a*) *Bio-assay Tests.*—Laboratory tests involving *in vitro* dipping of engorged female ticks have been continued on a number of the newer insecticides. Approximately 100 per cent. mortality is obtained with parathion at a concentration of 0.025 per cent., and at 0.003 per cent. concentration 69 per cent. of engorged females did not produce viable eggs. Field tests have confirmed the effectiveness of the lethal concentration indicated by laboratory tests, but the need for caution in using this material is again emphasized as it has caused a number of deaths overseas. Parathion has remained stable in distilled water in the laboratory for about nine months.

The toxicity of DDT-BHC mixtures has been examined, but some discrepancies have arisen and further work is necessary before any conclusions can be drawn. Following work on DDT-chlordane mixtures in the previous year, it is now proposed to proceed with field tests, although further laboratory work will be done with both DDT-chlordane and DDT-BHC mixtures.

Another of the new insecticides, dieldrin, has been found to be slightly less toxic than BHC, and it is similar to chlordane in its action on warm-blooded animals.

The effect of temperature on the toxicity of DDT is important. Laboratory tests conducted over a range of temperatures have shown that the mortality of the ticks increases with a decrease in temperature, indicating that better results may be obtained if cattle are dipped late in the day.

(*b*) *Effect of Long-continued Cutaneous Application of DDT Oily Solutions to Cattle.*—The examination of tissues taken from animals treated by weekly applications of DDT in peanut oil over a period of three years has been completed, and the results are interesting for several reasons. They show that (i) DDT is preferentially absorbed into adipose tissue; (ii) there is a tendency for the DDT content of the livers and spleens to rise when the animals are placed on a starvation diet, probably because they are drawing on fat reserves; and (iii) the tissues of control animals also contained DDT, although in significantly smaller quantities. This could have been absorbed by licking of treated animals, or by contamination of the pasture by DDT. None of the treated animals showed signs of DDT poisoning.

(*c*) *Investigations on DDT Dipping Fluids.*—Reports that graziers were dissatisfied with the kill of ticks when using DDT dips stimulated research to determine whether the cattle tick has developed some resistance to it. Preliminary work has concentrated on developing a technique for applying a known dose of DDT to the ticks, and this aspect of the problem has not yet been solved.

The sedimentation rate of some wettable powders has been examined, and several proprietary lines have been compared.

It was thought that the *pp'* isomer of DDT could be preferentially absorbed from dipping fluids, but tests on samples of field dips at least a year old do not indicate any reduction in concentration of the active isomer.

The loss of DDT caked on the bottom of the dipping vat has led to some experimentation with a model vat in order to determine if a modified bottom will render the DDT more available.

(*d*) *Biological and Ecological Studies.*—(i) *Sense Organs and the Questing Reaction of Tick Larvae.*—As a preliminary to the development of a field sampling method, the sense organs of the larvae were examined. Several organs were found (one of them apparently undescribed) which are suspected of being sense organs and could have some significance in explaining the ability of the larval ticks to find their host.

In the laboratory, larvae were allowed to ascend prepared grass blades, care being taken that they were not influenced by the observer, and their reactions to various stimuli were observed. They responded most strongly to the stimuli with olfactory components.

Mainly because of standardization difficulties, no attempt has been made to use olfactory stimuli in field sampling. However, it is proposed to follow up this work on questing behaviour under better conditions, using extracts of animal odours and synthetic substances.

(ii) *Sampling of the Larval Population in the Field.*—Several methods of sampling pastures for larval ticks have been tested, at Yeerongpilly until November and since that time at Rockhampton. In the most satisfactory of these, the observer wears a pair of tight-fitting white duck trousers as he walks through the pasture, making periodical stops to allow the larvae to be counted.

Observations are continuing for a year on a "ridge" and "creek-bank" plot in a paddock under normal management. It is hoped to lease an area of land on which cattle can be run as desired, so that more intensive investigations may be carried out on larval

survival in the field and on larval distribution in relation to cattle habits. These studies have directed interest to the role of the night resting-places of cattle in transmission of the tick.

(iii) *Studies on the Field Ecology of Non-parasitic Stages.*—The field ecology studies at Yeerongpilly were completed at the end of November, 1950. Broadly, the work confirmed that of the previous year. The ecological cycle in Brisbane is characterized by an almost complete cessation of production of viable eggs by engorged female ticks which fall on to pasture in the period April-July inclusive. It is estimated that there could be no more than four generations in one year under Brisbane conditions.

Over-wintering of the species is accomplished by the eggs and larvae of females which drop in late March and early April. The larvae which are picked up by cattle in late July develop into engorged females which fall in August. These are responsible for the rise in population during the late spring. The longevity of larvae on the pasture is an important feature in the survival of the species. As a check on the results obtained experimentally, in which the conditions were necessarily somewhat artificial, regular examinations were made on a dairy herd near Brisbane.

(iv) *Diurnal Cycle of Larvae.*—During the summer months the main feeding periods for cattle are the early morning and evening. Field observations of larvae have indicated that they are more readily available for pick-up before the heat of the day and possibly at dusk. The higher humidity in the early morning is thought to have an important bearing on larval behaviour.

(v) *Survival of Ticks in Nature.*—Studies have been commenced to obtain information on the survival of larval ticks in different situations, with a view to assessing the value of spelling pastures in maintaining a low level of infestation.

It has been observed that meat ants are responsible for the destruction of a high proportion of engorged ticks after dropping, but they do not consume larvae or eggs.

(vi) *Studies of Infestation on Stalled Cattle.*—This work, which was terminated in October, 1950, confirmed the finding reported last year, that the percentage of mature ticks is higher when the animals are prevented from licking themselves. There was also a considerable variation in the yield of engorged females on the same animals in separate infestations.

The mean time taken for a tick to mature and fall after attachment to the host was found to be 20 to 24 days, but the variation did not appear to be directly related to the season.

5. Development of Hybrid Dairy Cattle.

The experimental crossbred dairy herd at the F. D. McMaster Field Station has increased to 78 head of cattle, including 22 animals of the Jersey, Red Poll, Friesian, and Illawarra Shorthorn breeds. There are also three animals with 12.5 per cent. of Zebu, one with 18.75 per cent., 42 which have 25 per cent., seven with 37.5 per cent., and one with 75 per cent. The other ancestry of these cattle is from one or other of the European strains already mentioned. In addition, there are two purebred Zebus.

The investigation, which began in 1941 with one Zebu cow, now the progenitor of 56 head, has proceeded for ten years. Nine females with 25 per cent. and three with 37.5 per cent. of Zebu have either completed a lactation under test or are in milk under test on their first calf. A further six crossbred females, five with 25 per cent. and one with 37.5 per cent. of Zebu, will calve for the first time during the coming year. Production records under test continue to suggest that the crossing of European dairy breeds with the available Zebus gives rise to progeny with reduced milk production but with no appreciable change in the percentage of butterfat. Persistency and the milking rates of the crossbreds vary with the parentage of the animals.

The most notable feature of the year has been the establishment of close co-operation with the New South Wales and Victorian Departments of Agriculture. As a result, the registered Jersey "Richmond Colleen 3rd" and the registered Red Poll "Victoria Wennie" have been purchased at a nominal cost from the New South Wales and Victorian Departments respectively as part of a programme to uplift the genetic "ceiling" for production within the crossbred herd.

6. Investigation of Beef Production in Australia.

(*a*) *Survey of Beef-cattle Production.*—This survey has been continued. During the year the methods of beef-cattle production in Western Australia and in South Australia were examined and by the end of the year all field work in connexion with this survey had been completed. A first interim report on beef-cattle production in northern Australia was prepared for publication.

(*b*) *Studies of the Bovine Skin.*—The object of this investigation is to study the skin and hair covering. During the year observations were made on the seasonal variation in the "felting" propensities of the hair covering of beef cattle under Australian conditions. Morphological variations in the hair fibres, variations in skin thickness, and quantitative assessment and definition of follicular and glandular characteristics were also studied as complementary to the hair sample measurements.

It was found that the weight of hair per unit area and the morphological variations of the hair fibres, and hence the felting qualities, depend on the physiological control of growth and shedding of the fibres. A decisive shedding of the coat in springtime resulted in a hair sample which, when moistened and rubbed together, fell apart or had no discernible "felting" properties. Samples at the end of the winter from the same animals felted very strongly. The changes in the tissues associated with shedding were studied by microscopic techniques, and the degree and extent of shedding were measured in the microscopic sections of the skin. The biopsy skin samples were also used to devise and test a method for measurement of skin thickness. Inherent breed differences were found by this method. For example, the average skin thickness for the Jersey breed was 5.5 mm., for Hereford 7.0 mm., for Zebu 7.1 mm., for Afrikander 7.2 mm., and for Devon 8.2 mm.

The studies are being continued and extended.

(*c*) *Beef-cattle Feeding Investigations.*—The stall-feeding experiments and other observations at Talbingo (Tumut, New South Wales), made possible through the valuable co-operation of Mr. G. H. Hooper and financed by the Australian Meat Board, ceased during the year when Mr. Hooper decided to sell the property and stock. Nevertheless, through his assistance during 1949-50, complete information was collected on rations, food intake, body weight, and carcass weight of some 200 steers. The results have been analysed and a full report is being prepared. The work at Talbingo was initiated as a pilot experiment for more intensive studies to be carried out in Australia. It has shown that stall feeding of commercial beef cattle in Australia is sound economically under certain conditions, and that much depends on the relative prices of store stock and fodder and whether seasonal

conditions or the usual environment provide adequate grazing. Under conditions usually obtaining in Australia, stall feeding must be a short-term project which, in itself, introduces nutritional problems of a different kind from those encountered in other countries, such as North America, where stall feeding is practised for relatively long periods.

(*d*) *The Feeding of Beef-cattle under Stud Conditions.*—The results obtained with a wide variety of rations are being collected under excellent conditions of co-operation from two Hereford Studs in New South Wales. This work has already given very gratifying results in carcass-judging competitions and it is expected that the results will place cattle feeding under stud conditions on a sounder basis. Valuable nutritional data to supplement those obtained from stall feeding for topping-off purposes are being obtained.

(*e*) *Production Studies in the Southern States of Australia.*—The Australian Committee on Animal Production has arranged for facilities to be provided for regular weighing of cattle at selected centres in the Southern States. This project is being financed by the Australian Meat Board and will be controlled by the several State Departments of Agriculture. Its object is to obtain information on growth and fattening curves of beef cattle and so to measure the seasonal changes in the nutritive value of the pasture in a variety of environments. This work is to be co-ordinated by the Division of Animal Health and Production. So far, regular monthly reports of body weights, together with other relevant observations on seasonal conditions, are being received from three Stations, in South Australia, Victoria, and Tasmania.

IX. ENTOMOLOGY.

1. General.

The Division of Entomology, which has its headquarters at Canberra, is carrying out a research programme on insect pests and their control, on biological control of weeds, and on insect vectors in virus diseases of plants and animals. Its work is described in this Chapter.

Some of the work on insects that attack animals is being undertaken in co-operation with the Division of Animal Health and Production and is reported more fully in Chapters VII. and VIII.

Work on timber pests is also undertaken by the Division of Forest Products and is described in Chapter XIII., Section 7.

A more detailed report than that in Section 10 of this Chapter is given in Chapter X., Section 2 (*a*), on experiments by the Wildlife Section with the virus disease of rabbits, myxomatosis.

Division of Entomology.—The Division must primarily plan its work so that it is co-ordinated with that of the State Departments of Agriculture, which act in an advisory capacity to the primary producers and other industries concerned with insect pests. This co-operation has been maintained and to some extent strengthened during the year. Where an entomological problem is nation-wide or involves more than one State, the Division is expected to undertake specific research on that problem, but it must depend on the State Departments for assistance and its work must be complementary to theirs. In this category may be placed such problems as the control of the Argentine ant, termites, the earth mite, cattle tick, locusts, pasture cockchafers, pasture caterpillars, pests of stored products, and others.

However, some problems of a more fundamental or general nature are usually not attempted by the States. In this category are four principal fields of research which are at present receiving attention in the Division of Entomology: (i) the relationships between insects and their environment; (ii) the physiology and toxicology of insects; (iii) biological control of weeds and insect pests; and (iv) the transmission of virus diseases by insects.

The development of new insecticides has given rise to a number of problems, since these highly toxic materials, by giving a high percentage kill of both insect pests and their natural enemies, create abnormal conditions in insect populations, especially when certain species are resistant to them. A clear understanding of the fundamental principles that govern insect populations is necessary so that each problem can be more easily dealt with as it arises and, what is perhaps more important, improved control of pests may be attained by modifying the application of control measures.

Similarly, the studies in progress on the physiology and toxicology of insects are designed to determine weaknesses in the natural protection of insects in the same way as studies on their biology and ecology will indicate weaknesses in their life cycles or habits.

Biological control, in addition to the practical work of introducing and spreading insects to control other insects or weeds, is necessarily bound up with population and ecological studies. This has been clearly demonstrated at Bright, Victoria, by investigations, now drawing to an end, on the chrysomelid beetles introduced to control St. John's wort.

With the phenomenal spread of the rabbit virus, myxomatosis, during the summer of 1950-51, the Wildlife Section requested assistance in a study of insect vectors of the virus, and the Division is co-operating fully in this work.

A co-operative programme of work with the respective States on the control of the Argentine ant in Sydney and in Western Australia has given very promising results, which indicate that it may be possible to effect complete eradication of the ant. Further trials in progress and planned for the near future should establish whether or not eradication is possible.

Taxonomic work which will facilitate the correct identification of insects and thus enable us to draw more readily on the work of other investigators has been continued by many officers of the Division. A new field has been opened by the commencement of investigations on pasture caterpillars, the importance of which has not been fully realized in the past. An officer has been appointed to concentrate on the pests of stored products, which constituted one of the most important problems handled by the Division during the second world war.

2. Cattle Tick.

Details of research on the cattle tick are given in Chapter VIII., Section 4. The scope of the work is summarized briefly below.

(*a*) *Bio-assay Tests.*—Laboratory tests have been continued to determine the toxicity of several new insecticides to the cattle tick, and their effect on the viability of eggs laid by treated females. Results of the last few years' work are being prepared for publication.

(*b*) *Effect of Long-continued Cutaneous Application of DDT Oily Solutions to Cattle.*—This experiment, commenced three years ago, is now complete, and the results show how DDT is absorbed into the animal tissues.

(*c*) *Investigations on DDT Dipping Fluids.*—Adverse reports regarding the kill of some DDT dips have stimulated laboratory research to find the reason.

(*d*) *Biological and Ecological Studies.*—Observations were continued on all stages of the tick at Yeerongpilly until November, 1950, and thereafter at Rockhampton. Work has been concentrated mainly on the non-parasitic stages and on the development of methods of sampling larval ticks in pastures.

3. Sheep Blowfly.

Research on the sheep blowfly is described in Chapter VII., Section 18. The following is a brief summary of the work.

(*a*) *Insecticides for Protection against Body Strike.*—The effect of a branding fluid base in extending the period of protection given by DDT is being investigated.

(*b*) *Dressings.*—It has been shown that commercial preparations of DDT and BHC, when liberally applied, appear to be suitable for treating small strikes, and provide a temporary treatment for large strikes.

(*c*) *Ecology of Sheep Blowflies.*—Experiments are being continued to investigate the reaction of blowflies to baits, and further studies have been made on the breeding of blowflies in carrion.

(*d*) *Life-history Studies.*—Additional information has been accumulated on the breeding-places of Australian Calliphoridae.

(*e*) *Distribution of Calliphoridae.*—Some interesting records are being obtained from collections made in various parts of Australia.

4. Insect Physiology and Toxicology.

The work under this heading is carried out with the object of obtaining a better understanding of the physiology of insects, and of using such knowledge to indicate better methods of applying insecticides.

(*a*) *Digestion of Wool by Insects.*—In continuation of earlier studies on the mechanism of digestion of wool by larvae of the clothes-moth *Tineola*, the hydrogen-ion concentration and the oxidation-reduction potential of the digestive juices have been re-examined and more accurate data obtained. The fate was also investigated of a large number of elements following ingestion.

Tineola larvae have been found to be able to detoxify a wider range of metals and non-metals (many of which are ordinarily highly toxic) than most other animals.

An investigation has commenced on various aspects of the metabolism (particularly sulphur metabolism) of clothes-moth larvae and this has necessitated a careful chemical examination of the faeces. Uric acid is the predominant material and occurs to the extent of about 40 per cent. About 6 per cent. cystine is present, together with smaller amounts of sulphate sulphur and urea.

(*b*) *Production of Uric Acid by Insects.*—Uric acid is a characteristic component of insect excreta, but almost nothing is known of its method of formation in the tissues. The site of uric acid synthesis is being examined and a study of the biochemistry of the process in isolated tissues and enzyme systems has begun.

(*c*) *Insect Muscle Biochemistry.*—A study on enzyme kinetics of the muscle apyrase in relation to its two substrates, ATP and ADP, has yielded some interesting results.

Viscosity studies have been carried out on actomyosins prepared by different methods from both thoracic and femoral muscles of insects, and have revealed widely differing physical properties of the proteins from the two types of muscle.

(*d*) *Cuticular Proteins.*—Further work has been carried out on the protein of insect cuticles, including identification of the free carboxyl groups. The water-soluble protein has been shown to be heterogeneous, a number of components being present whose isoelectric points range from four to six. One component is present to an extent of about 50 per cent. and it has been isolated and studied.

An investigation is in progress on the structure and properties of the hardened protein occurring in insect cuticles. Several modified protein fractions have been isolated and are being studied. It has been shown that the enzyme polyphenol oxidase is able to oxidize the phenolic groups of tyrosine to the quinone without removal of the tyrosine from the protein chain. This quinonoid protein then acts as a tanning agent.

(*e*) *The Composition of the Honeydew Produced by Australian Coccids of the Genus Ceroplastes.*—The honeydews produced by three of the four species of wax scale insects belonging to the genus *Ceroplastes* which occur in Australia have been examined. It has been shown that the honeydews excreted by *C. destructor*, *C. ceriferus*, and *C. rubens* contain the sugar alcohol adonitol (ribitol) and for *C. destructor* and *C. ceriferus* this is the only carbohydrate material present. The honeydew excreted by *C. rubens* contains, in addition to adonitol, glucose and another unidentified reducing sugar. The honeydews produced by these three scale insects contain amino acids and proteins. The sap of three host plants for these scales contains adonitol. It is considered that the insects ingest and excrete the adonitol unchanged.

(*f*) *Insect Haemolymph.*—In a programme of work on insect haemolymph, differences in the composition of the larval and prepupal haemolymph of *Calliphora* spp. (blowflies) are being investigated. Since the last larval cuticle is hardened to form the puparium this work should throw considerable light on the changes which occur during the hardening of insect cuticle.

The nature of the pigments responsible for the green colour of the larval haemolymph of *Pieris rapae* is also receiving attention. The colour is due to the presence of carotinoid and bile pigments.

(*g*) *Influence of Nutrition on Reproduction.*—A study of the effects of nutrition on reproduction of sheep blowflies is in progress. Limitation or inadequacy of larval food produces smaller flies than an adequate diet. There is a close correlation between adult size and the number of ovarioles present and this in turn influences the reproductive capacity of the adult.

The stages in ovarian development on various diets are being followed. Fertilization does not influence rate of egg development, although this is retarded by short-duration anaesthesia with carbon dioxide.

5. Biological Control.

Active research is in progress on the control of various introduced weeds and insect pests by means of beneficial insects introduced from their native habitat. Other problems in this sphere of activity are being considered, and up-to-date information on some of them is available following the visit of an officer of this Division to Europe and America.

(*a*) *St. John's Wort.*—(i) *Ecological Studies at Bright, Victoria.*—Investigations were commenced at Bright in 1948 to assess the effectiveness of *Chrysomela gemellata* Rossi and *C. hyperici* Forst. as controls of St. John's wort and to seek guidance for future experiments in the entomological control of weeds.

This programme was found to involve a good deal of basic research on the biology of the insects and of the weed. A study was made of the ecology of the weed, its methods of reproduction, resistance to defoliation, aggressiveness, and the competition of associated flora with it. The effectiveness of control by pasture improvement and frequent cultivation was also studied.

Detailed studies were made of the beetles to facilitate identification of immature stages and to determine the life history and behaviour of each species, together with the physical and biotic factors causing mortality. Their general ecology was also studied.

These investigations have shown that an undisturbed stand of St. John's wort is maintained entirely by vegetative reproduction, and much of the local spread takes place by suckering. Some seeds remain viable in the soil for at least five years. Consequently, after an

area has been cleared, seedling regeneration will continue for some years. This can be controlled by developing an almost complete ground cover of other herbage, particularly subterranean clover, which is maintained by annual manuring with superphosphate or by frequent cultivation. The ability of plants to survive defoliation was found to vary with their size and age and with soil type and moisture conditions. Unless a high percentage of the wort plants was destroyed, vegetative reproduction usually resulted in re-occupation of the vacant spaces in a very short time.

Field studies have shown that, when numerous, *Chrysomela gemellata* can almost completely destroy any type of well-established *Hypericum* stand, whereas *C. hyserici* has only a limited ability to kill the plant. The latter consistently reduced seed production, but this had no particular value in controlling the weed. Because of their outward movement from the original colony sites, both species often failed to attack the seedling growth which followed destruction of the original stand. However, their tendency to avoid timbered areas frequently forced them back to the worked-over area.

Extensive destruction of the weed has occurred consistently only in areas of abandoned farmland and in some pine plantations where suitable cover for the insects is available. It appears that there is little chance of control in eucalypt forests, where most of the infestation occurs and where other means of control are least practicable.

The insects may prove useful in treeless grazing land too steep for cultivation, where the wort could be replaced by useful pasture species.

Investigations at Bright emphasize that detailed attention should be given to the flora associated with a weed, firstly to ascertain the extent to which other plants are likely to assist the insects, and secondly to determine the species likely to replace the weed.

(ii) *Liberation of* Chrysomela *Species.*—Additional liberations of *Chrysomela hyperici* and *C. gemellata* have been made in selected localities throughout New South Wales, and the help of officers of the Victorian Department of Lands and Survey in the collection of material has been invaluable. They have been making further liberations in Victoria. Reports have been received from parts of New South Wales, where liberations have not previously been made, that the growth of St. John's wort is very heavy, and these areas will be examined with a view to distributing the beetles there.

In several districts officers of the New South Wales Department of Agriculture have co-operated in this work, both by making liberations and by making observations on the resultant establishment of the beetles. The Mid-Western County Council has also co-operated.

The beetles have increased in abundance in many districts, while in others there appears to have been a reduction in numbers. All sites where liberations have been made are being kept under observation and supplementary liberations are made where it is considered desirable.

Small numbers of *Zeuxidiplosis giardi*, the gall-midge of St. John's wort, emerged from the consignments introduced from Europe last year. In spite of all efforts, however, the insects failed to establish themselves in the insectary.

(*b*) *Cabbage Moth.*—Further field liberations have been made of *Angitia cerophaga* and *Diadromus collaris* in all States of the Commonwealth, though liberations of the former have been gradually diminished as evidence of its general establishment accumulated. In the period under review six liberations of *Angitia* have been made and 34 liberations of *Diadromus*, some 12,000 specimens in all being released in the field. *Angitia* is probably generally established, and in New South Wales at least is extremely abundant and widespread. *Diadromus* has been recovered on a number of occasions, but does not yet appear to be very abundant. *Plutella* seems to have been far less numerous this year in New South Wales.

Field studies on experimental plots have yielded interesting data on the abundance of *Plutella* and the large number of parasites and hyperparasites associated with it.

Plans have been made for the introduction of cultures of *Diadromus collaris, Diadromus subtilicornis,* and *Apanteles plutellae,* all parasites of *Plutella,* from continental Europe.

(*c*) *Cabbage Butterfly.*—Liberations of *Apanteles rubecula* throughout the Commonwealth have been continued, 23 liberations, totalling about 5,300 specimens, having been made during the year. Some recoveries at a number of points have been made and this parasite is probably well established.

From field studies made on experimental plots, much information has been obtained on the relative abundance of *Pieris* and the three established parasites (*A. rubecula, A. glomeratus,* and *Pteromalus puparum*). Parasitism reaches practically 100 per cent. during the summer.

(*d*) *Green Vegetable Bug.*—Further work has been carried out with the parasite *Trichopoda pennipes,* but difficulty has been experienced in maintaining a culture of this parasite. Nevertheless, three liberations have been made during the last year, and in one area parasitized hosts were found shortly after the liberation was made. An attempt is being made to maintain a culture of the host and parasite throughout the winter.

(*e*) *Potato Moth.*—Little work has been done on this species and its parasites during the year, but plans have been made for a field survey to ascertain which of the various parasites liberated in past years have become established.

(*f*) *Red Scale.*—The Chinese parasite or red scale, *Comperiella bifasciata*, introduced from California a few seasons ago, is established in South Australia where it can be readily recovered.

(*g*) *Queensland Fruit Fly.*—Following the outstanding results obtained by American workers in Hawaii against *Dacus dorsalis,* arrangements have been made to attempt to utilize some of these parasites against Queensland fruit fly and other fruit flies in Australia.

(*h*) *Heliotropium europaeum.*—The possibility of the biological control of this serious weed, which causes toxaemic jaundice in sheep, has been under consideration. A survey of the literature and a field study carried out in the western Mediterranean have indicated that a flea beetle, *Longitarsus albineus,* may prove useful. An officer of the Commonwealth Bureau of Biological Control is engaged in studying further the possible value of the insect.

(*i*) *Red Spider.*—Two shipments of *Stethorus vagans,* the ladybird predator of red spider and other mites, were obtained in Canberra with the co-operation of local orchardists and forwarded to the Division of Biological Control, University of California.

6. Population Dynamics.

When seeking to control insect pests our object is so to reduce their population level that the damage they cause is economically negligible. The method generally used is to kill the insects, either by applying insecticides or by introducing natural enemies. However, even when a new control measure produces spectacular results initially, the good results are by no means always maintained when the method continues to be employed over a number of years. This is because we are dealing with a complex system of

equilibria which always tends to become readjusted in such a way that on the average the number of births equals the number of deaths in any given time. In the production of this readjustment there is a strong tendency for the population to swing back towards the level existing before the new method was introduced. Only by understanding the nature of this equilibrium system can we expect to employ control measures intelligently and efficiently.

Experiments designed to elucidate this equilibrium system have been continued, using the sheep blowfly as the experimental animal. Much of the work during the past year has been concerned with evolving better experimental methods and constructing special apparatus. With the improved methods many of the preliminary results have been confirmed, and a better understanding has been reached of the causes and nature of the population oscillations that occur when the sheep blowfly is limited only by food which is supplied at a constant rate. In addition, new experiments have been set up to explore the influence of other factors on the blowfly population.

By considering the experimental results in relation to all available published information concerning animal populations, it has been found possible to formulate a general theory to account for the natural control of animal populations. This theory was developed from the examination of certain fundamental processes known to influence populations, and the widely diverse facts known about animal populations all fit into it naturally, although previously many of these appeared to conflict with one another.

7. Locusts and Grasshoppers.

The outbreak of the Australian Plague Locust that was expected to develop in the season 1950-51 did not materialize. Swarms were practically confined to the Western Division of New South Wales and adjacent parts of South Australia. This seems to have been due to the unprecedented floods that occurred in the major outbreak areas of New South Wales during the spring. The local rainfall was so heavy that even areas that were not flooded developed a pasture too tall and dense to be favorable for the locust. As a consequence there was no increase in numbers over those of the autumn of 1950, and the few swarms that hatched in the Bogan-Macquarie Outbreak Area soon disintegrated. The wet conditions were followed by an extremely dry spell commencing in December, and this further reduced the population. An interesting observation of the hatching of eggs in an area near Trangie that had been under water throughout the winter confirmed conclusions reached earlier that eggs can withstand very wet conditions for long periods as long as the temperature remains below the hatching threshold.

The spring floods caused a considerable loss of trees and shrubs from the tree-barrier experiment on the Trangie Experiment Station. *Myoporum montanum* was particularly badly affected and most of the plants of this species have now succumbed. There were also about 20 per cent. of deaths among the *Atriplex nummularia*, but the spreading habit of this species has prevented any appreciable gaps from appearing in the barrier as a result of the losses. In the tree-barrier plots on "Myall Mundi" many Myoporums were barked by rabbits during the very dry autumn of 1951. From one cause or another this species seems to be gradually disappearing from the barriers, leaving *Atriplex nummularia* as the only effective species.

It was hoped that the rabbit-proof netting might be lifted from the tree-barrier plots during the autumn as the first step towards submitting the barriers to normal grazing pressure. However, the very dry conditions and the great abundance of rabbits led to the postponement of this step until later in the winter.

Considerable progress has been made in the revegetation of the scalded areas under study, but the season has been so favorable to plant growth that the permanence of this improvement cannot be guaranteed.

An extension of earlier work on the relation between trees and locust abundance has been undertaken during the year. In the earlier observations the naturally-occurring belts of trees studied were so narrow that movement of locusts into them from adjacent cleared country was mainly responsible for the relatively high numbers observed within the belt. Although a marked diminution in locust abundance was recorded as one penetrated into the belt, and this was found to be correlated with the density of the trees, the factor of inward movement of locusts prevented any conclusions being drawn as to the population that could be permanently maintained within really extensive timbered areas. Larger areas have now been located in central and northern New South Wales, including a wide range of tree density from almost virgin conditions to a spacing sufficiently wide to cause little or no interference with pasture growth. Preliminary counts of locusts have been made in these areas, but systematic observations must await a rise in the general locust population.

Taxonomic work on grasshoppers has been continued, particularly on the genera *Chortoicetes* and *Austroicetes*, which include the two most injurious Australian Acrididae.

8. Cockchafers.

A long-term experiment on the control of the pasture cockchafer, *Aphodius howitti* Hope, has been concluded. In the Canberra district, a single treatment of a sown pasture with 3.3 lb. DDT per acre gave an effective control of the species for the three years following that of application. A return towards normal levels of infestation was noticeable in the fourth season. In this experiment the DDT was applied as a 2 per cent. dust. A further trial was made using DDT-impregnated superphosphate, spread by a drill at the rate of 1.7 lb. DDT and 95 lb. superphosphate per acre. The degree of control was not as high as in the former experiment (in which virtually complete control occurred in the first year), but was sufficient (68-87 per cent. control) to reduce the grub population to levels at which no detectable damage occurred.

The study of the ecology of *Aphodius* has been furthered by data gathered on field surveys of the distribution of this cockchafer, and by laboratory and field experiments.

Recent investigations have confirmed two hypotheses concerning the ecology of *Aphodius*, namely, that oviposition occurs twice, and that the survival of the species is not dependent upon the presence of dung. The first oviposition occurs before feeding begins, and may take place in the soil where the adult was formed, resulting in the observed tendency for infestation patterns to be repeated for several successive seasons. Not only does this primary oviposition precede feeding, but the number of eggs laid is approximately double that of the secondary oviposition. The species is therefore capable of maintaining itself indefinitely in the absence of dung, as on golf-link fairways and lawns.

Other work carried out has included the completion of the field survey of the distribution of *Aphodius* in New South Wales and Victoria, where the geographical limits of the species are now known with considerable accuracy. Further studies have been made of the ecology and control of those scarabaeids involved in eucalypt defoliation, of those damaging turf, and of a South American scarab (*Cyclocephala signaticollis* Burm.) recently introduced to this country.

Improved techniques for the preserving and storage of larvae have been developed.

The programme of rearing, identification, and description of scarabaeid larvae has been continued on an increasing scale. The yield of adults from material collected in 1950 was better than that of preceding years, owing to improved rearing techniques.

9. Red-legged Earth Mite.

Experiments have been continued on methods of application to pastures of DDT, which was earlier found to be effective against the red-legged earth mite, the pest of subterranean clover in southern Australia.

The previous year's experiments indicated that the application of DDT-superphosphate mixtures to pastures by means of the broadcaster or "spinner" did not give satisfactory results, and this year experiments were undertaken with a power dusting machine. The results, although not up to expectations, were considerably better than the broadcaster treatments, but still did not compare with those in small-scale experiments. Drill applications tended to give slightly better results. DDT applied by drill at the rate of 90 lb. of 1 per cent. dust in superphosphate per acre gave an 80 per cent. kill of mites at the beginning of the season and reduced the damage to the young clover plants to less than 10 per cent. of that in the untreated control plots. Field applications at this rate quickly lose any residual effect and the mite population may return almost to normal by the end of the season, but the pasture has been protected from severe mite attack at the time of germination when the clover seedlings are most vulnerable. It has already been shown that mite attack after the first fortnight of the growing period has little or no effect on the final yield of subterranean clover.

The DDT dust may be applied at any time during the late summer months—March or April—but applications should be delayed as long as possible and the best results may be expected from treatments applied within a week of the commencement of the first autumn rains.

Observations during all field dusting operations with broadcaster, drill, and power duster strongly suggested that much of the DDT is lost in wind drift and convection currents and it is considered that the relatively inefficient control achieved by the above DDT treatments of pastures on a large scale is due to this factor. Further experiments have in fact shown that all the effective DDT is contained in the fine dust of the mixtures. Highly effective control can, of course, be obtained by a substantial increase in the amount of DDT used.

In an effort to overcome the difficulty of drift, a 50 per cent. granular form of DDT was obtained. Applications equivalent to 90 lb. of 1 per cent. dust per acre were made but with disappointing results due, it is thought, to the fact that relatively few of the highly concentrated granules were used in each treatment so that the mites in their random movements failed to make contact with the granules sufficiently often to pick up a lethal dose. Experiments are now being undertaken in which an effort is made to incorporate the DDT within superphosphate granules to produce a 1 per cent. mixture which will form a more continuous cover on the ground and none of which will be fine enough to be carried away by wind drift.

The use of DDT against the red-legged earth mite in pastures also infested with the lucerne flea (*Sminthurus viridis* L.) is not recommended, as this insecticide is completely non-toxic to the latter insect. It is, however, toxic to the natural predator of the lucerne flea, the Bdellid mite (*Biscirus lapidarius* Kr.), and in small-scale experiments DDT treatment has resulted in a marked increase in the number of lucerne fleas present.

Experiments have been begun this year from which it is hoped to obtain detailed information on the short- and long-term effects of mite attack on the yield and composition of an established subterranean clover pasture. Caterpillar infestations, should they occur, will also be taken into account.

Samples of several new insecticides have been obtained and will be used in experiments on both the earth mite and the lucerne flea.

10. Insects and Viruses.

(*a*) *Myxomatosis.*—The most important development during the year was the initiation of work on the insect vectors of myxomatosis. In the early work on the disease a considerable amount was learned about the potentialities of insects as vectors. With the emphasis placed on blood-sucking Diptera in the recent epizootic, information is needed on a number of points not previously examined. A programme, in collaboration with Professor F. Fenner, of the Australian National University, is planned to obtain data on the laboratory aspects of mosquito transmission.

(*b*) *Physiology of Virus Vectors.*—In continuation of the work reported last year on the uptake of radiophosphorus by the jassid *Orosius,* the feeding of this and other species of jassids has been examined further. The species differ in their preference for different plant tissues. *Limotettix* prefers to feed on the phloem of its host plants, and this should make it an efficient vector of phloem-inhabiting viruses. An examination of the mechanism by which it finds this tissue has refuted the generally accepted hypothesis that phloem-feeding jassids find their preferred tissue by means of a gradient of hydrogen-ion concentration from the plant epidermis to the vascular bundle. The evidence indicates that jassids actually locate the tissues on which they prefer to feed by random probing with their mouth-parts.

An interesting observation on the transmission of spotted wilt of tomatoes by the thrips vectors is that adults are unable to transmit the disease unless they have fed upon an infected plant when in the larval stage whereas larvae are infective after a latent period of a few days. This has been known for a long time, but no explanation has previously been suggested. The hypothesis has now been advanced that the virus is destroyed by oxidation in the adult alimentary tract, but is protected in the larvae, and experimental evidence is being accumulated to test this hypothesis.

(*c*) *Transmission of Plant Viruses.*—Work has been continued on the transmission of witches' broom of lucerne and tobacco yellow dwarf. It has proved to be extremely difficult to transmit the former from one lucerne plant to another. It seems possible that this does not normally occur in the field, but that transmission to lucerne normally takes place from weeds harbouring the virus.

An attempt is being made to determine if other species of jassids than the common brown leafhopper are capable of transmitting these virus diseases. Particular attention is being paid to the species of *Limotettix* mentioned above, to species of *Euscelis, Eurinoscopus,* and *Nehela.* Laboratory colonies of these have been established, but so far positive transmission has not been obtained.

11. Termites.

During the past twelve months 512 test colonies of *Nasutitermes exitiosus* and 118 of *Coptotermes lacteus* were installed in standard laboratory tests of timbers, preservatives, &c. These standardized tests have included native commercial timbers, building boards, plywoods, and plastic cable coatings.

Among the more important test results, *Eucalyptus alba,* which is being imported into Australia for railway sleepers, showed about the same termite resistance

as red mahogany (*E. resinifera*), telephone cable coverings of polyvinyl chloride were badly damaged, whilst polythene coverings showed only slight surface injury, and progress figures on the second group of Australian commercial timbers indicated that they may be placed in the following order of decreasing resistance: *Syncarpia laurifolia, Eucalyptus paniculata, E. tereticornis, E. crebra, E. grandis,* and *E. microntha.*

A temporary field station has been set up in North Queensland to carry out laboratory testing with *Coptotermes acinaciformis* and to carry out preliminary investigations on the maintenance of laboratory colonies of *Mastotermes darwiniensis.*

Field testing of timbers and preservative treatments in co-operation with the Division of Forest Products has continued and the twenty-first annual report on the condition of samples in the International Termite Exposure Tests has been prepared and forwarded to Madison, United States of America. All the above tests are being carried out with *N. exitiosus* and *C. lacteus.* During the past year scout tests have been installed in the Riverina in an endeavour to locate test sites for other species such as *Rhinotermes* and *Coptotermes frenchi.*

The third annual examination of the soil poisoning tests installed around mounds of *N. exitiosus* showed that creosote and 5 per cent. pentachlorphenol (both used at the rate of 0.5 gal./cu. ft. soil) have given complete protection for three years; 5 per cent. sodium pentachlorphenate and 10 per cent. sodium arsenite (both at 0.5 gal./cu. ft.) have both given complete protection for two years; 5 per cent. DDT at 0.5 gal./cu. ft. has given complete protection for one year; lead arsenate and white arsenic both at the rate of 4 oz./cu. ft. soil failed to give complete protection for one year. During the past year, similar tests of creosote, 5 per cent. pentachlorphenol, and 5 per cent. DDT were installed around mounds of *C. lacteus.*

A successful method of carrying out field tests of building boards has been developed, by means of which such boards can be exposed to severe termite hazard and, at the same time, protected from exposure to sunshine, rainfall, and soil moisture.

Approximately 70 series of termites have been received for identification during the past year. Most of these were collected by an officer of this Division in the Burdekin area, North Queensland, and they have provided additional distribution data for several economic species.

12. Argentine Ant.

(*a*) *Barrier Spray Experiments.*—The discovery of infestations of the Argentine ant (*Iridomyrmex humilis* Mayr.) in the Sydney metropolitan area in April, 1950, led to a co-operative pragramme of investigations by entomologists of the New South Wales Department of Agriculture and this Organization. The climatic conditions of Sydney are comparable with those of the main infestations in Western Australia and permit experiments to be carried out over the greater part of the year.

Three experiments were carried out at Lidcombe, New South Wales, and the work was extended to Western Australia in February, 1951, to confirm the results of the New South Wales investigations under the dry summer conditions there. The investigations in Western Australia were carried out in co-operation with officers of the State Department of Agriculture and Department of Public Health. Following these investigations an isolated infestation, 9½ acres in area, at Lidcombe was treated in April, 1951, with 2 per cent. chlordane spray in an attempt to eradicate the Argentine ant from this area.

The insecticides were applied with the object of creating barriers of insecticide between each house and the area outside the residential block. Kerbs, fences, foundations of houses and out-buildings, trunks of trees, and the borders of all paths and garden beds were treated. The effectiveness of each treatment was assessed by comparing the activity of the ants before treatment and at regular intervals after the insecticides were applied. The activity in each residential block was obtained by a system of ratings of the average number of ants present in a known length of each trail occurring in "standard" positions in the block. These ratings permitted the results to be treated statistically.

The New South Wales experiments were begun in late winter, late spring, mid summer, and autumn to gain information on any seasonal effect of treatment. The first two experiments resulted in excellent control of the Argentine ant by a spray containing 2 per cent. chlordane, which was slightly superior to 2 per cent. DDT. Later experiments showed that a mixed spray containing 1 per cent. chlordane and 1 per cent. DDT was comparable in effect with the 2 per cent. chlordane.

Comparative experiments at Shenton Park, Western Australia, confirmed the New South Wales results and sprays containing 2 per cent. chlordane, or 1 per cent. chlordane and 1 per cent. DDT, were again the most effective treatments. An infested area bounded by four streets and containing nine houses and a bakery was treated with 2 per cent. chlordane which resulted in almost complete control. The effectiveness of the treatments was reduced by the presence of ripe grapes in home gardens, which prevented operators from making a thorough treatment of vines and trellises.

In these experiments a total area of more than 20 acres was treated in New South Wales, while in Western Australia the total exceeded 5 acres.

Treatments of individual household blocks with 2 per cent. chlordane in both Western Australia and New South Wales resulted in complete control of the ants but did not prevent reinfestation by ants from adjacent infested areas.

(*b*) *Baits.*—Investigations into the development of an improved bait were continued at Lidcombe, New South Wales, and a method of comparing baits was developed. It was found that the U.S.D.A. Argentine ant bait was the most attractive to the ants and that baits containing sodium arsenite were significantly more attractive than control baits without sodium arsenite. Baits containing chlordane, DDT, toxaphene, and dieldrin attracted few ants.

13. Other Investigations.

(*a*) *Caterpillars of Pastures and Field Crops.*—From time to time caterpillar plagues damage pastures and field crops in many parts of the Commonwealth. Some species, such as *Heliothis armigera,* are well-known pests and have received the attention of entomologists in most States, but there remains a residuum of species usually grouped under such general names as "cutworms", "army worms", "webworms", &c., about which our knowledge is far from adequate. A study of these important caterpillar pests has recently been begun, and it is hoped that the information gained about their identity, distribution, ecology, and habits will lead to more effective methods of controlling outbreaks.

During the course of the red-legged earth mite investigations, severe infestations of the pasture webworm (*Talis pedionoma* Mayr.) occurred in many of the experimental plots. Losses of up to 85 per cent. of the grass component and up to 51 per cent. of the total yield of the pasture were caused. The reduction in yield amounted in some cases to 24 cwt. per acre. However, none of the DDT-treated plots suffered damage and it was shown that applications of DDT-superphosphate mixtures applied at the rate of 90 lb.

of 0.25 per cent. dust per acre during the late summer months gave complete control for one season. Two per cent. DDT applied at the same rate gave protection for two years.

(*b*) *Insect Pests of Stored Products.*—An officer has been appointed to continue the war-time work on grain storage and to investigate problems arising in stored-product entomology generally.

The initial period has been taken up in a study of grain storage and handling methods as practised in the different States and in an assessment of the entomological problems involved. As a result of this study, it is considered that underground storage is well worth consideration and it is hoped that an experimental chamber will be constructed in order that detailed observations may be carried out.

Preliminary attention has been given to the problems facing the flour milling industry, which are necessarily related to conditions found in the wheat industry because many insects enter the mills in the grain stream. Useful control of insects infesting mills need not, however, wait on the elimination of insects from the grain.

In the laboratory, cultures of many of the more common stored-product pests have been established in order that material may be available for experimental work.

(*c*) *Meat Ant.*—(i) *Control Work.*—Comparative tests with DDT and chlordane for the control of the meat ant (*Iridomyrmex detectus* (Smith)) were made in February, 1951, near Canberra, Australian Capital Territory. Spray treatments, and the application of a band of 2 per cent. dust around the nests, were ineffective. Dusts containing 2 per cent. DDT and 2 per cent. chlordane respectively, when blown into the entrance holes of nests at the rate of ½oz. to each entrance hole, effectively controlled the ants. The DDT dust did not prevent ants from neighbouring colonies from re-occupying the treated nest sites, but the chlordane did so in spite of repeated attempts. Four of the six nests treated with 2 per cent. chlordane dust were free of ants three months after treatment. The remaining two contained very small colonies.

(ii) *Incipient Colonies.*—One hundred incipient colonies, resulting from a nuptial flight in March, 1950, were marked and some nests opened up for examination at approximately monthly intervals. The excavated females were contained in a single gallery 3½–5 in. deep, the top of which was sealed off. Eggs were laid within the first four weeks, larvae appeared in November, and entrance holes were opened up in only two colonies in January and February, 1951. At this time the colonies contained up to 21 workers and a similar number of larvae. The fact that the ants are still confined in the ground fourteen months after the female excavated her first gallery provides a possible explanation for the apparent failure to control meat ants from a given area completely. The few remaining marked colonies will be left until October, 1951, before further examination is made.

(*d*) *Timber Borers.*—Investigations on the biology of *Lyctus brunneus* have been concerned almost entirely with the nutritional requirements of the larvae. This work has shown that successful development can take place on a diet in which the carbohydrate : protein ratio is 15 : 1, and as the normal ratio in wood is 3.3 : 1, this throws interesting new light on the nutrition of wood-boring insects.

The technique of rearing the larvae on a synthetic food medium is now being used to investigate the toxicity of various alkaloids which appear to confer immunity to *Lyctus* attack on certain timbers.

(*e*) *Insecticidal Formulations.*—Some preliminary work has been done over the past year with the object of producing stable aqueous dispersions of DDT. The solvent property of chlordane for DDT has been utilized in this respect and the results have shown that the use of chlordane has several advantages. Without the application of heat, emulsions can be formed of particle size comparable with that of the most satisfactory preparations at present available and the DDT is prevented from crystallizing and settling out of suspension. Chlordane itself has a high insecticidal value, and it can replace the solvents formerly necessary in DDT emulsion concentrates. The toxicity of a liquid DDT-chlordane residual deposit would be expected to be higher than that of a dry crystalline deposit of DDT.

(*f*) *Susceptibility of Houseflies to DDT.*—A strain of housefly which had been bred in contact with DDT by Mr. D. Maëlzer, of the Zoology Department, University of Western Australia, was compared with our standard ("Stock") laboratory strain and found to tolerate 8–10 times as much DDT as the "Stock" strain.

When the "Stock" strain was compared in susceptibility with a strain developed from individuals collected in Queanbeyan, approximately seven miles from Canberra, it was found that the Queanbeyan ("Wild") strain could tolerate approximately 30 times as much DDT as the "Stock" strain. DDT has been used to a limited extent in the locality in which the progenitors of the Queanbeyan strain were collected.

In an attempt to determine the reliability of the results of the tests with the "Stock" and "Wild" strains, another strain of flies is being developed from individuals collected at Black Mountain, where it is assumed that DDT has not been used to any great extent. Comparisons of susceptibility will later be made between the "Stock", "Wild", and "Black Mountain" strains.

(*g*) *Standard Common Names of Insects.*—In entomology, as in other fields of biology, scientific names are universally used by specialists engaged in research work, so that they do not usually have any difficulty in identifying an insect by name. It is inevitable, however, that common names should be used by the layman, and it is equally inevitable that the same insect should be known by different names in different places.

Attempts to standardize such names have met with considerable success in other fields, for example, in commercial timbers. Officers of this Division have been working for some time on the preparation of a list of standard common names of insects and allied forms occurring in Australia and have circulated it throughout Australia and overseas for comment and criticism. After considering all the comments received, the inter-divisional committee responsible for this project prepared a third draft list, which was presented to the Australian and New Zealand Association for the Advancement of Science meeting in Brisbane in May, 1951, with a view to its approval by a representative gathering of Australian entomologists and subsequent publication at an early date.

14. Taxonomy.

Taxonomic work on various groups of insects has been continued by specialists both within the Division and elsewhere.

The specialist working in Melbourne on a grant from the Organization has completed the first part of a monograph on the Australian ants and this is now in the press. The revision of the Australian locusts and grasshoppers is being continued by a United States authority on this group.

The Diptera (flies) of Australia are being examined with particular reference to the blowfly groups and many of the parasitic flies which are important beneficial insects. The main groups at present under examination are the Tachinidae, Nemestrinidae, Calliphoridae, and Apioceridae. The examination of the Chalcidoidae, a group of important parasitic wasps,

is a long-term project and must continue for many years before the group can be satisfactorily revised. A vast quantity of Chalcid material has been collected during the last 12 months, principally from the Burdekin area of North Queensland and from Tasmania. Attention has also been given to other families of predaceous and parasitic wasps. Studies are continuing on the Australian Tortricidae, a moth family which contains several pests, and on various groups of the Hemiptera (bugs). Taxonomic work is also being done on the Blattidae (cockroaches) of Australia.

Many additions have been made to the Division's collection during the year. As mentioned above, fairly extensive collections were made in the Burdekin area, North Queensland, and another collection was made in Tasmania. Identifications of insect specimens have been made for institutions and individuals throughout Australia, together with some from New Zealand and the Pacific Islands, and other places overseas. Some important problems have arisen in connexion with the quarantine of timber from overseas, and the Division has assisted the Department of Health by obtaining information about the insects concerned and their treatment.

X. WILD LIFE.

1. General.

The Wildlife Section was established in 1949 to undertake investigations of mammals and birds, native or introduced, of economic importance. It was understood that, at first, attention should be concentrated on the rabbit, the importance of which to Australia's rural production and economy needs no emphasizing. An account of the progress of the rabbit investigations will be found in Section 2.

In the general field of wild life research falls the study of mutton birds which has for some years formed part of the programme of the Division of Fisheries, and which is discussed in Section 3 below.

2. Rabbit Investigations.

(*a*) *Myxomatosis.*—The work on the virus disease, myxomatosis, has been given priority in the Section's programme. The first field trial, begun at Gunbower, Victoria, early in 1950, was followed up by a series of six somewhat smaller trials in localities further up the Murray, i.e. near Rutherglen in Victoria and Corowa and Albury in New South Wales. With the partial exception of the trial at Wymah near Albury, where one or two warrens on the experimental site were substantially depopulated, the results of all these trials confirmed the conclusion from earlier work, carried out by the Division of Animal Health and Production, that the disease could not be expected to spread effectively without the assistance of blood-sucking insects.

Possible insect vectors, particularly mosquitoes, were kept under close observation during the trials, and in December, 1950, it became apparent that they had suddenly assumed an active and effective role. The result was the rapid development of a widespread epizootic, in the course of which the infection was carried to, and spread along, practically every river system in New South Wales west of the Divide, into northern Victoria, southern and south-western Queensland, and into South Australia as far as the Lake Eyre region and Eyre's Peninsula. The efforts of State Departments and to a lesser extent of individual landholders resulted in the introduction of the infection to areas not reached by the natural spread, and thus it has also appeared in one or two coastal areas. Although myxomatosis failed to make much headway in many of the districts affected and no significant reduction in the local rabbit populations was noticeable, very large numbers of rabbits were killed in some areas and many landholders received substantial benefit.

During the course of the epizootic, investigations and surveys were carried out by the Section's officers in most of the main regions involved, and an attempt was made to assess the conditions favouring the development of high local infection and mortality rates, a sound understanding of which is necessary before it will be possible to exploit the virus to maximum advantage as a weapon of control. Valuable assistance was given in this work by the State authorities concerned with vermin control.

Special attention was given to the insect vector aspect, and it was possible to demonstrate that the night-biting mosquito, *Culex annulirostris,* was the principal vector along the Murray main stream, and that in one locality a species of *Simulium* played a part in the transmission of the disease. Circumstantial evidence pointed to sandflies as probable vectors in one region. In general it was found that the distribution and intensity of the disease were correlated with the known or presumed prevalence of water-breeding, blood-sucking insects. Thus except in the regions that had suffered widespread flooding (e.g. areas watered by the Lachlan and the upper tributaries of the Darling), the infection tended to be confined to narrow strips of land bordering rivers and swamps.

(*b*) *Basic Ecological Studies.*—Although the investigations under this head, and also (*c*) and (*d*) below, had to be drastically curtailed in favour of the myxomatosis work, some useful information has been obtained on rabbit behaviour, breeding rates, feeding habits, faecal refection, natural controls, parasites, etc. A short study of the effect on a rabbit population of predation by the Little Eagle (*Hieraëetus morphnoides*) is at present in the press. During field surveys carried out in connexion with the myxomatosis epizootic, data on the regional aspects of the rabbit problem were collected.

The work falling under this heading is regarded as one of the most important features of the Section's programme, and the field station recently established at Albury is intended primarily to facilitate these long-term studies.

(*c*) *Poisons and Poisoning.*—A laboratory assessment has been made of the relative toxicities and acceptability of most of the poisons now in use, together with some not hitherto employed for rabbit control. Of the latter, the only material showing promise is sodium fluoracetate ("1080"). It was found that this poison could be successfully incorporated into standard baits such as thistle root, carrot, and boiled oats, and preliminary field trials indicated that it had some advantages over strychnine. It is less costly and its greater acceptability may enable free-feeding to be dispensed with, although this practice appears to have distinct advantages.

Some attention was given to two recently developed toxic materials in the organo-phosphate group, primarily with the idea of developing baits whose dangerous "life" could be limited. These were "Hexone", containing hexaethyl-tetraphosphate and tetraethyl-pyrophosphate, and "Folidol", containing parathion. It was found that the former probably hydrolysed too rapidly to be of much practical use, while the latter seemed to have an extremely low acceptability.

(*d*) *Fumigation.*— Intensive inquiries have failed to discover any material likely to have a significant advantage over the fumigants already in use and attention has, therefore, been concentrated on the possibility of improving the efficiency of application of standard fumigants, of which chloropicrin seems

to be by far the most promising from this point of view. With the co-operation of the Organization's Central Experimental Workshops, a unit has been designed and built for blowing a chloropicrin-oil aerosol into and through rabbit warrens. Preliminary trials have yielded very encouraging results.

3. Mutton Birds.

The joint field investigations on the Tasmanian mutton bird (*Puffinus tenuirostris*) in the Furneaux Island region by the Organization and the Tasmanian Fauna Board have been continued. Two periods of field work are conducted each season in order to obtain data on longevity, homing, dispersal, and other aspects of the biology of the species. Fisher Island, a small sanctuary islet near Lady Barron, is used as a research island. There are three rookeries on it, and during the 1950-51 season they totalled 145 breeding pairs. During the field work in November-December, at the egg-laying period, an endeavour is made to ring as many of the adult birds as possible, and this year 90 per cent. were caught and so marked. Of these, 21 per cent. were birds which had returned to the island for the fourth successive season since being marked. This is a minimum figure as an unknown number of birds had lost their original copper rings before being ringed with the more durable monel metal rings now in use. So far no bird ringed as a fledgling during the present investigations has returned to Fisher Island to breed.

Before the opening of the commercial birding season on 23rd March the field party ringed 1,868 young birds on the commercial islands. On the basis of the number of rings returned by the birders at the end of the commercial season the proportion of young birds actually taken, out of the presumed total available, was as follows, the corresponding figures for 1949 (the last complete year) being given in brackets: Great Dog Island, 54 (62) per cent.; Little Dog Island, 55 (71) per cent.; Little Green Island, 51 (67) per cent.; Babel Island, 30 (41) per cent. In conjunction with the commercial statistics these data will allow an approximate estimate to be made of the populations of the various islands. To improve the existing statistical system for this purpose a new method of reporting catches, with fuller details of the operatives engaged in the industry, was instituted during the year. In the season under review 445,556 birds were taken on the islands, which, with their various by-products such as oil and feathers, were valued at £20,000 to the producers. The total production for 1949 was 441,071 birds.

The mortality counts on Cronulla Beach, New South Wales, were continued during the last quarter of 1950, and for the eighth successive year a low mortality was found. The last severe mortality among the southward moving stream of migrating birds along the east Australian coast took place in 1942, after a series of more or less heavy mortality years. The only year when this mortality was of sufficient severity to extend to the breeding grounds in Tasmania was 1934, when dead birds of the species were found washed up as far afield as Stewart Island in New Zealand. The cause appears to be starvation and some correlation has been found with tuna abundance at this season. Usually poor southern bluefin years appear to coincide with years of heavy mutton bird mortality.

XI. FISHERIES.

1. General.

Investigations related to the exploitation and development of Australia's marine resources are carried on by the Division of Fisheries, which has its head-quarters at Cronulla, New South Wales. Work on the preservation of fish is undertaken by the Division of Food Preservation and Transport (*see* Chapter XII., Section 6).

Division of Fisheries.—The work of the Division of Fisheries is reported in the remainder of this Chapter.

During the year the Division's work at sea has been done from three research vessels operatiug full time on oceanographical and biological work. It is planned to extend the oceanographical work of the Division and for this purpose preliminary plans were prepared during the year for an approximately 175-ft. oceanographical research vessel to be constructed in Great Britain.

The Division's work at Dunwich Field Station, Stradbroke Island, south Queensland, has been directed towards investigating the distribution and movements of mullet in the estuarine and river phases of their life history; the development of the oyster industry in Queensland; observations on the distribution of prawns; and, latterly, the investigation of an epidemic among oysters in southern Moreton Bay and preliminary work on lagoon fish farming. Hydrological data are collected concurrently with all these investigations. The facilities of the station have been increased by the addition of a 35-ft. launch and a large net dinghy.

The laboratory at Thursday Island, Torres Strait, has been equipped, and study of plankton and the biological study of pearl oysters have made progress. A 45-ft. ketch has been purchased and is being fitted out as a pearling lugger to facilitate the study and collection of pearl shell in the area.

2. Operations of Research Vessels.

(*a*) F.R.V. *Warreen.*—The F.R.V. *Warreen* has, in Western Australian waters, maintained the Rottnest offshore traverse during the year, and a similar traverse was again accomplished, after a long delay, off Albany. The latter part of 1950 was devoted to experimenting with long-line methods of catching tuna and making a search for small pelagic fish in the neighbourhood of Geraldton. No success was achieved and trolling indicated comparatively few tuna in the area.

At the beginning of 1951 the ship was equipped with a modern echosounder and a Cornish style ring-net. With these instruments the biology and methods of capture of pilchards were studied for four months along the south coast of Western Australia. This work has proved conclusively that pelagic fish shoals can be detected in Australian waters by means of a suitable echosounder and that shoals of the Australian pilchard will give a form of trace comparable to that obtained from shoals of, for example, the Cornish pilchard. Other less definite forms of trace may also be obtained from pilchards, but these and the forms of trace given by other species of shoaling fish require considerable investigation.

Although catches of np to four tons of pilchards per haul were taken with it, the Cornish ring-net does not seem to be the most efficient form of net for this fishery. Further, the evidence so far obtained from the echosounder indicates (as has long been suspected) that the pilchard shoals in the waters studied are neither large nor dense and are layered rather than in massive vertical concentrations. They each contain at most only a few tons, but are at times undoubtedly numerous and widespread.

During the course of these investigations, bluefin tuna were encountered on several occasions in extensive bodies. No echosounder trace attributable to these fish has so far been obtained, although a number of frigate mackerel (*Auxis thazard*) were obtained on one occasion when the ring-net was shot on the evidence of an echosounder trace.

(*b*) F.R.V. *Derwent Hunter*.—In the early portion of the year F.R.V. *Liawenee* made one cruise in Tasmanian waters. Her charter period was completed and she was returned to the Tasmanian Government in October. F.R.V. *Derwent Hunter*, a powered wooden ketch of 71 feet, one of the newest and largest vessels in the Tasmanian fishing fleet, was purchased for the investigations of the Division in south-eastern waters. She made four cruises in Victorian and Tasmanian waters during the year and worked on barracouta, shark, and deep-sea fish.

Experiments in long-line fishing have been made at depths between 200 and 400 fathoms on the edge of the continental shelf, in waters which have probably never before been fished. Particular attention was paid to the western end of Bass Strait. Some of these hauls yielded results of great interest and commercial promise. The deep-sea trevally (*Hyperoglyphe porosa*), generally considered a rarity, was taken in fair quantities. Other species obtained were the hapuku (*Polyprion oxygeneios*), which is a valuable fish in New Zealand, and a cod (*Mora*) which is probably a new species. Large prawns were also taken by trapping at these depths.

(*c*) F.R.V. *Stanley Fowler*.—During the year the F.R.V. *Stanley Fowler* has investigated the occurrence of tuna in south-eastern waters, trolling from Newcastle to Gabo Island, extensively in Tasmanian waters, from Hobart to Sydney, and from Brisbane to Eden. The investigation aimed particularly at plotting the distribution of southern bluefin tuna and striped tuna in the area. Surface temperatures were taken at half-hourly intervals while the ship was steaming, and traverses up to 40 miles off shore using the bathythermograph were made off Jervis Bay, Bateman's Bay, Bermagui, and Eden.

(*d*) M.V. *Villaret*.—For six weeks in August and September a survey to investigate crayfish potentialities in the archipelagos lying north-eastwards from North-west Cape, Western Australia, to the Montebello Islands and Sholl and Fortescue Islands, was made in the chartered, refrigerated M.V. *Villaret*. Although over 1,600 specimens of the crayfish *Panulirus versicolor* were taken and reasonably large populations of this species were found in parts of the area, it was amply demonstrated that the methods employed for the capture of *P. longipes* in more southerly waters were inapplicable to the northern species. Considerable additions to knowledge of the biology of *P. versicolor* were made.

The cruise also indicated that the areas visited, which are at present unexploited, are capable of supporting limited fisheries based on netting mullets, leatherskins, darts, and north-west salmon, and possibly on trolling Spanish mackerel and sea-pike. The results warrant further work in the area, and the fostering of commercial interest. It will, however, be necessary to evolve an efficient method of trapping the indigenous crayfish before they can be exploited commercially.

3. Sea Fisheries.

(*a*) *Barracouta*.—Previous work on barracouta, which is still one of the two most important species in the Australian commercial catch, has shown it to be under-exploited. Although supply often exceeds demand, the reverse applies in certain years, especially in Tasmania, where (because of the existence of canneries) there is still a good market for the species. Furthermore, there is in every locality an off season when barracouta are scarce. It would be valuable to find out where the fish go in the off season and to know the causes of scarcity in bad years.

The work in the past two and a half years has shown that the fishing season for barracouta at any locality is broadly the spawning season of the species in that area. These seasons vary from place to place. Most individuals reach sexual maturity at 50-60 cm. of fork length. Barracouta also feed during these seasons, but never become fat. In the off season they probably move in search of food, and it is possible that at that stage, when the gonads are resting, the barracouta are fatter than at any other time. In South Africa, where observations on this species were recently made by an officer of the Division, the specimens caught at the spawning season resemble those marketed in Australia, whereas those caught some months earlier are nearly twice as fat and correspondingly more valuable. It is now proposed to study the regional and seasonal distribution of the main organisms eaten by barracouta in Australia, in order to obtain an indication of barracouta distribution in the off season. In the search echo-sounders and special fishing gear will be used.

There are indications that several populations of barracouta exist in the area of the fishery, and that any migrations are of the order of hundreds rather than thousands of miles. There is unlikely to be much intermingling between the winter-spawning barracouta of eastern Victoria and New South Wales and the summer-spawning fish of western Victoria and Tasmania. Length-frequency data from canneries (from about 50,000 fish) also indicate the existence of at least two stocks (north-western and south-eastern) in Tasmanian waters. The attempt to obtain direct evidence by tagging has not so far been very successful, only six tags having been returned out of over 4,000 released. One of these tagged fish had crossed Bass Strait, but the other five were recaptured close to the tagging area. There is evidence of shedding of tags, and new types of tags (including the Oslo hydrostatic type) are now being used.

(*b*) *School Shark*.—The recoveries from the tagging of over 1,000 adult sharks at sea have given valuable information on the stocks of school sharks in the south-eastern Australian area. The stock is a homogeneous one extending from South Australia through Bass Strait to the Victorian and Tasmanian areas. Further work is required to determine the growth rate and migration of the adults, but the investigation has now reached a point where results can be prepared for publication and conservational measures recommended for this fishery.

(*c*) *Tuna*.—In Western Australia the *Warreen* made no contact with tuna during the latter half of 1950 but in 1951, during the pilchard work on the south coast of Western Australia, interesting tuna data were forthcoming. From previous observations no great concentrations of southern bluefin were deduced to occur in this section, the aerial observations confirming the results of trolling. However, during the current cruise of the *Warreen* (No. 38) a fair quantity of tuna has been caught by trolling. Furthermore, instead of the catches being confined, as in previous seasons, to first- and second-year fish (i.e. fish of less than 10–12 lb. individual weight), there were appreciable numbers also of larger tuna (three-year-old and even four-year-old fish), though the last-mentioned were only occasionally caught. The largest fish taken weighed 27 lb. The two smallest size-groups (i.e. the regularly occurring groups) had a somewhat lesser size range than has been the rule in former years. One fish of the first-year group was the smallest so far taken in Australian waters.

Another feature of the unusual tuna conditions on the south coast of Western Australia was the capture of striped tuna off Albany for the first time in these records. The previously known southern limit was the Abrolhos. The frigate mackerel also was taken on the south coast for the first time.

In eastern Australia tuna investigations from the F.R.V. *Stanley Fowler* were concentrated particularly on southern bluefin and striped tuna. The 1950-51 season for southern bluefin was a poor one. In 1949-50

good catches were made by fishermen trolling on the New South Wales coast, but this year even M.V. *Senibua,* an American tuna clipper equipped for live-bait and pole fishing, took only a few small catches, amounting to 244,953 lb. of southern bluefin. In 1949-50, southern bluefin occurred in the Bermagui-Eden area during September and November but this year, owing to an earlier and stronger intrusion of tropical waters from the north, migrations were affected so that the northern migration to New South Wales waters was very protracted and occurred in July. Southern bluefin appeared in Tasmanian waters in October and November. Fishermen in the Fortescue Bay area of Tasmania caught a few fish close inshore, but these were apparently stragglers from the main schools which moved further south. It is also interesting to note that the specimens were large (130-150 lb.) and were caught as late as May.

As water temperature observations were regularly taken by bathythermograph, it was possible to observe a definite correlation between sea temperatures and tuna occurrence. Southern bluefin prefer a temperature around 18° C.

The 1950-51 season for striped tuna was favorable in south-eastern Australia. This species is not subject to the fluctuations in abundance so common in southern bluefin. The exceptional sea temperatures of the past season also affected the occurrence and migration of this species. The bathythermograph traverses indicated well-defined temperature bands in coastal waters. Striped tuna prefer a temperature between 16.5 and 19.0° C., and it was found that they move in the band of water most closely approximating this temperature.

Fishing methods used during the investigation included trolling and long lining. The long-lining experiments were unsuccessful, but the tests were not considered exhaustive. Several types of jig were tried in trolling and the plain polished aluminium jig was found most satisfactory. It was concluded that a two-man boat could take a paying catch in a good tuna season such as that of 1949-50, but in a poor year such as 1950-51 it would be economically hazardous for the fisherman. Striped tuna can be readily hooked but the weakness of the jaw means that only about one fish is landed of every four hooked. It is unfortuate that the American tuna clipper M.V. *Senibua,* which was experimenting in Australian waters last season with the live-bait polefishing method, should have chosen a poor year for southern bluefin and could not remain to try out the method on striped tuna in Tasmania. As a result of previous work by this Division, it was shown that not only is the striped tuna more plentiful than bluefin tuna, but also it can readily be taken by the live-bait method of pole fishing.

The tuna results of past years are now being prepared for publication.

(*d*) *Pilchards.*—The oil content of the pilchard is a matter of great commercial significance in the large pilchard oil industries of North America and South Africa. It has been repeatedly shown in Australia that the season at which pilchards are most easily found and caught in any locality is that at which they spawn, and at which their oil content is consequently very low (less than 5 per cent. of the fish weight).

It has also been predicted that pilchards taken at other times of the year would tend to be fatter. At King George's Sound, Western Australia, pilchards are most conspicuous and easily caught in May and early June. However, the samples obtained in this area in April, 1951, were richer in oil; the percentages ranged from 5.7 to 8.6, the higher values being obtained in the first half of the month.

Even such fish as these probably would barely repay the cost of oil extraction, as the average oil content of similar fish so treated overseas is about 9 or 10 per cent. However, the trend of the figures suggests that still higher percentages would be found in pilchards taken in earlier months, and the matter will be investigated. The main difficulty is to locate the pilchards in reasonable quantities except at the spawning seasons, as they appear to leave the surface waters. However, it is hoped to discover them by systematic echosounding.

(*e*) *Australian Salmon.*—Considerable attention has been paid to the nature of the salmon fishery on the coastline of south-western Victoria and South Australia. The south-western area of Victoria fails to support a regular salmon fishery. Fish of 2-3 lb. in weight are often taken, but their appearance from year to year is entirely sporadic. The greatest quantities of salmon appear in the summer months, though occasional catches are made in winter. At no locality are fish greater than 3-4 lb. netted, although occasionally larger salmon are taken by anglers. There are numerous reports of large schools of such salmon being sighted at distances 8–10 miles from the shore. However, in South Australian waters salmon appear to be present throughout the year. The main catches are made during the summer months, when an inshore movement occurs. The two main fishing areas are near Port Noarlunga, south of Adelaide, and between Port Lincoln and Ceduna in the western area. Apparently all sizes from 3 to 10 lb. are available, but the larger fish are not popular in the market or the Port Lincoln cannery.

The occurrence of large salmon (5-10 lb.) in South Australian waters suggests that these obviously mature fish must have a spawning area somewhere within the Bight, as it is difficult to envisage an annual spawning movement so far afield as to the south-western corner of Western Australia, where it is definitely known spawning does occur.

Racial studies have been confined to the western subspecies of salmon, comprising those from Tasmania, South Australia, and Western Australia. No racial difference has yet been found between fish from these States, although a comparison of gill-rakers, fin-rays, scale counts, and body proportions has been made.

Experiments were carried out with various types of tags. It was proved that disk tags, though giving a satisfactory return, were too difficult to attach under Western Australian fishing conditions. The internal tag was compared with the opercular tag in experiments at Cheyne Beach, Parry's Inlet, and Hamelin Bay. At Cheyne Beach 46 per cent. of 127 opercular tags and 64 per cent. of 118 internal tags were recovered. At Parry's Inlet 40 per cent. of 85 opercular tags and 10 per cent. of 51 internal tags were recovered. At Cheyne Beach the tagging was done when salmon were actively feeding and before they commenced the usual pre-spawning movement. The fish remained in this area for a considerable period while the fishery was active, which explains the high percentage of recoveries. Of the recoveries, seven fish travelled distances of 50-220 miles in periods of 10-49 days, all in a westerly direction.

(*f*) *Ruff* (Arripis georgianus).—The ruff is virtually unknown in eastern Australian waters. Victoria supports a small fishery, concentrated in the Port Phillip Bay area and realizing about 1,000 lb. annually. In South Australian waters the ruff is present in large quantities all the year, providing an active fishery in the winter months during an inshore movement. The fishery over a period of years has produced from 100,000 to 300,000 lb. annually. Western Australia has, during early winter, an active fishery based upon spawning concentrations. In 1949, 500,000 lb. were taken.

The ruffs of all States are being subjected to a preliminary population analysis to determine the usefulness of various racial characters such as gill-rakers, fin-rays, scales, and body proportions.

A small preliminary tagging experiment was carried out in Western Australia using operculum clip-on tags.

From 250 fish released, 5 per cent. were recaptured but no movements were indicated. The use of a more suitable tag will be necessary, the operculum being much too weak to support the clip-on tag for any considerable period.

4. Estuarine Fish.

(*a*) *Mullet.*—The sea mullet (*Mugil dobula*) provides about 40 per cent. of the total fish catch in Queensland and New South Wales. Stocks have been subjected to intensive fishing, and are being studied with a view to their being sustained.

The year's work has been concentrated on the freshwater and estuarine phases of the life history. Mullet of the first two-year groups are distributed all over the estuaries and up into fresh water. The older fish concentrate in the fresh waters except during the spawning migrations, when they pass downstream and concentrate in large schools in the estuaries before passing out to sea on the spawning run. There are exceptions to these generalizations. Not all adult fish migrate every year. Presumably spawning is not necessarily an annual affair. Also, small groups of adult fish can be found in the lower estuaries even during the non-migratory season and, with the size group immediately below the first-spawning size, furnish the mullet catch during the non-migratory season.

Tagging of mullet has continued in both Western Australia and Queensland. All fish returned during the year were recaptured in the same general area where they were tagged, the furthest travelled fish having moved about 40 miles from one end of Moreton Bay to the other.

(*b*) *Fish Farming.*—The permission of the National Park Trust has been obtained to use Maianbar (Cabbage Tree Creek), opposite the Cronulla laboratory, as a fish farm. A preliminary contour survey of the area has been made. It is proposed to reconstruct the original fish gate and wall and to build one or more nursery ponds inside. When the ecology and hydrology of the lagoon are known, fish will be introduced in an endeavour to show whether the large number of similar lagoons can be profitably converted into fish farms and so increase the existing yield of mullet, whiting, bream, and blackfish.

Preliminary work has commenced on an experimental fish farming experiment on a brackish water lagoon on Moreton Island near the Dunwich (Queensland) laboratory. The lagoon was cleared of over 200 boxes of fish, mostly mullet and whiting, and it is intended to restock with small mullet under "natural" conditions. Later the lagoon will be fertilized to compare growth rates of mullet under the resulting conditions and to assess the possibility of using this type of fish farming, which is common in tropical countries, in Australia.

5. Freshwater Fisheries.

(*a*) *Tasmanian Whitebait.*—The northern stock of this species appears to have been depleted (*see* Second Annual Report) and at the request of the Division all fishing was prohibited in the 1949 season. The Division's recommendation that the 1950 catch be restricted to 100 tons was not agreed to, but actually this figure was not exceeded because the whitebait migrated upstream to spawn much earlier than usual, and so largely escaped the attentions of fishermen.

(*b*) *Trout Investigations (Tasmania).*—The study of the trout fishery, based on the returns of anglers' catches, has been continued. Good runs of both brown and rainbow trout were experienced during the spawning seasons, and much valuable information on these mature fish was collected, while several hundred fish were tagged. Recent spawning runs have shown a considerable improvement in condition over last year in both kinds of trout, and returns of tagged fish have been satisfactory. With the provision of suitable equipment it is intended to extend the survey to include the younger fish in rivers and lakes.

(*c*) *Fish Farming.*—Fundamental work in the study of the ecology of fish farming is proceeding satisfactorily. With the different methods of enrichment used this year, noticeable changes have taken place in the phyto- and zooplankton of Lake Dobson. The increase in plant life was such as to colour the normally clear water a distinct green, which lasted for two or three months. The animal population is being increased and natural shelter for invertebrate benthic fauna is developing rapidly. It is hoped that it may soon be possible to stock the lake with fish.

With the co-operation of a landowner the application of this work to farmers' dams is now being studied.

6. Crustacea and Shellfish Investigations.

(*a*) *Crustacea.*—(i) *Western Australia (Panulirus longipes).*—The range of the commercial species *Panulirus longipes* in Western Australia has now been determined as extending from Cape Leeuwin in the south to North-west Cape in the north to a depth of about 45 fathoms. The range of maximum population density lies between Garden Island in the south and Point Charles (Quobba Point) in the north. *Jasus lalandii,* the southern crayfish, has been traced from Cape Naturaliste to Hopetoun in isolated occurrences. No commercial tests have been made of the population density of this species in Western Australian waters.

Panulirus versicolor, the banded crayfish of the Indo-Pacific, was found to occur sparsely in the region extending from North-west Cape to the Montebello Islands and in reasonable concentrations from Mary Anne Passage to Sholl and Fortescue Islands. The crayfish could not be trapped by the normal type of baited craypot, but would enter cans used as shelter pots. Numbers were collected from reef areas, and furnished an attractive, easily-processed, frozen product of good flavour, with a high flesh weight recovery (40-42 per cent., cf. *P. longipes* 32-34 per cent.). The size grouping and population density at Fortescue and Sholl Islands suggested that this area represented one margin of the area of maximum population density. Males of the species were moulting in July-August. Females were moulting, and showed the black sternal spot of fertilization, in August. Some females carrying eggs were taken, also in August.

Further data on age grouping, including spine-counts, and measurements of "white" crayfish known to be in the first year of maturity, confirmed the earlier findings, based on the analysis of length and weight frequencies, that the age groups of *Panulirus longipes* which are marketed represent the late second, the third, and the fourth years from the puerilla or natant crayfish stage, and that this species matures in the third year from the natant stage. It was found also that the species yields its best return in tail weight against total weight during the third and fourth years from the natant stage, and that the present minimum legal carapace length of 2¾ inches protects the majority of the crayfish only to the end of the second year from this stage. It does not thus ensure either that the best weight of flesh is obtained from a given total weight of processed crayfish, or that the species is protected from capture during the first year of maturity. About half of this age group would be protected with a minimum legal carapace length of 3 inches, and about three-quarters with a minimum legal length of 3¼ inches.

During the six years from 1943 to 1950, the commercial catch of *P. longipes* has increased from 763,996 to 7,007,000 lb. The greater part of the increase has resulted from the exploitation of accumulated stock

on newly-worked coastal reef areas, some of which have been discovered during the survey work of this Division. The Western Australian Government has followed the advice of the Division in many measures aimed at the rational exploitation of the crayfish populations. The majority of the fishermen and processors co-operate in the observance of these measures.

The Abrolhos crayfishery occurs in an area which is considerably overcrowded with fishermen but for various reasons the Divisional recommendation that the number operating there be restricted to 60-65 men has not been implemented. The result is that the 1951 fishery will represent the second year of an experiment on the effect of virtually continuous fishing at a known rate on a known population of crayfish with a known replacement rate during the period of the fishery. The data are being analysed progressively and promise to make a valuable contribution to theory.

The preparation of an attractively frozen product from *Panulirus longipes* presents many difficulties, the chief of which is a tendency to a number of types of flesh discoloration during processing. Intensive empirical investigations have been carried out into the cause and control of these effects, which can be grouped broadly as follows: direct iron-sulphur interactions giving intense, localized black spots; copper-ammonium-sulphur reactions giving generalized bluish-gray stains; tyrosinase-melanin reductions giving generalized greenish-black stains, particularly in bruised crayfish; and the discoloration of carotenoid storage in the flesh, pink in moulting crayfishes, orange and blood red in females with ripening ovaries.

The spectacular rise in the fishery is due largely to the fact that it has been possible, following the careful observance of the processing precautions which have been developed as a result of these investigations, to present the frozen tails on the American market in a condition at least equal to the produce of hitherto more favoured species from other countries.

Histological examination of gonads and of cuticle, using standard methods, has not proved satisfactory. Initial experiments involving heat fixation and the examination of sections, unstained, using phase contrast microscopy have given encouraging results. An Altman-Gersh fast-freezing fixation unit is also under construction.

(ii) *Tasmania* (Jasus lalandii).—The plankton work at Port Arthur and the tagging work being carried out by interested fishermen at certain selected areas have been designed to secure preliminary information about the southern marine crayfish in order that a detailed programme may be prepared for a later intensive investigation. So far it has been shown that 1948 was a poor brood year for larval crayfish in the Port Arthur area. Subsequent years have shown good production of larval crayfish there. The tagging work has given preliminary data on growth rates of mature crayfish and has shown limited migrations of crayfish in some areas.

(*b*) *Oysters.*—Inquiries from oyster farmers for assistance in learning modern oyster farming techniques have, in Queensland, increased greatly over the last six months. The Division's test area at Southport has been abandoned because the almost continuous spat-fall renders it admirable for spat catching but impossible to work successfully as a growing area. A report on the possibilities along the southern Queensland coast was published for the benefit of oystermen.

During the autumn and early winter of 1951 great mortality occurred amongst oysters in southern Moreton Bay, Queensland. It appeared to be the result of an epidemic disease. Examination of the symptoms suggests that a virus may be responsible and this theory is being tested.

The Pacific oysters imported to Tasmania in an attempt to provide an industry there have continued to thrive and, during the prolonged warm summer of 1951, seem to have given rise to a more satisfactory spat-fall than in the previous two years. However, it is believed that the stocks could be built up at a greater rate by the provision of a larger brood-stock, and it is hoped to augment the numbers during the coming summer.

(*c*) *Scallops.*—The object of this investigation has been to determine the life history and growth rates of the commercial scallop and of the possible causes of fluctuations and variation in quality of the d'Entrecasteaux Channel scallops. This fishery is continuing to show sharp decline in each year's catch. It dropped from 290 tons in 1949 to 210 tons in 1950, and the present season's catch is expected to show a further drop. The highest catch, 500 tons, was taken in 1947. From biological investigations it appears that there has been virtually no production of young scallops since about 1940 and that the industry has been dependent on broods produced before 1941. The stocks from these broods are becoming further depleted each year, since they have received no substantial recruitment.

In the period 1949-50 several areas showed the presence of young scallops on the beds, but it is calculated that it will be at least four or five years before they reach the legal minimum size. The juveniles are not sufficiently prevalent on all beds to warrant optimism about the industry being supported for a long period on these broods. Diving examination of several beds gave valuable information on the distribution and behaviour of scallops. Other aspects which have been investigated are quality changes in the catch, fishing intensity on the beds, growth rates of juvenile scallops, and onset of sexual maturity in these juveniles.

This work indicates that the roe development of the scallop, which influences commercial quality, shows a positive correlation with the water temperature before the opening of the scallop season. Quality has declined progressively since 1947.

(*d*) *Pearl Shell.*—The aim of the Division's pearl-shell programme is to establish feasible methods for the culture of pearls and pearl shell. This year attention has been directed mainly to the life histories and habits of the various species of pearl oysters, but at the same time information relevant to pearl-shell culture has been gathered.

Unfortunately, very little information has been gathered about *Pinctada maxima*, the commercial pearl shell, owing to a shortage of material. However, supplies of *P. vulgaris* and *P. sugillata* have been available.

7. Hydrology.

(*a*) *Oceanic Investigations.*—Deep-sea traverses off Rottnest Island were continued during the year. Results confirmed the former evidence of weakly-defined current systems in this area, with a rather severe depletion of nutrients in the shallow surface layers.

Three officers of the hydrological section took part in two cruises with R.R.S. *Discovery II.* in August and October, 1950.

(*b*) *Onshore Investigations.*—Routine shelf stations were sampled regularly on the coasts of New South Wales and Tasmania, the latter stations being worked by *Liawenee* and more recently by *Derwent Hunter*. Data supplied by the Meteorological Bureau supported the hypothesis of a correlation between a long-term increase in phosphates and atmospheric pressure factors which have been responsible for a very slight change in mean annual sea-level since 1942.

The recent introduction of several additional shelf stations off the south-western Australian coast will help to elucidate productivity cycles in this area. The use of vessels supplied by the Western Australian Fisheries Department now makes it possible to maintain sampling with a frequency equivalent to that on the eastern coast of Australia.

(*c*) *Estuarine Investigations.*—Attention is being concentrated on the estuaries of northern New South Wales, which, being flood-dominated, maintain a relatively high phosphate level. Routine monthly surveys of estuaries in the central New South Wales area were continued during the year. Owing to the remarkably high rainfall during 1950 run-off characteristics were abnormal compared with previous years.

In July, 1950, a hydrological programme for the southern part of Queensland was initiated. It is supervised from the hydrological laboratory at Dunwich.

Routine sampling of Tasmanian and south-western Australian estuaries was continued during the year.

(*d*) *Oyster Hydrology.*—Because of the leaching out of phosphate added to the mud on the lease, progress of fertilization experiments at Shell Point, George's River, has been slow. By placing the mixed fertilizer (consisting of superphosphate and linseed oil meal) in boxes which have been sunk a foot or so into the mud this difficulty has been largely removed. Diffusion of phosphate from these enrichment centres has been slow but steady.

Observations of mud and water temperatures over the lease were continued during the winter of 1950 and were recommenced in May, 1951. A plankton pump is now in routine operation at the lease. The water over the lease is pumped through three sieves, of 200, 100, and 40 meshes to the inch, and the dry weight of plankton caught by each sieve is determined. It is hoped that this work will indicate quantitative seasonal fluctuations in plankton populations in the area of oyster growth.

An intertidal area in Tilligerry Creek, Port Stephens, was tested with the equivalent mixture during the year, and already the nutrient properties of the treated mud have shown a slight improvement. The effect of run-off during the coming winter on these properties will be studied.

During the year apparatus was assembled at the Chemistry Department, University of Western Australia, to develop techniques for the determination of radio-active isotopes, particularly phosphorus. This work is only in the experimental stages, but it is expected to be of great value in following the successive stages of nutrient regeneration and assimilation in bottom muds.

(*e*) *Freshwater Hydrology.*—In Lake Dobson, Tasmania, there has been some development of algal growth along the rows of enrichment, but nutrient levels in the water itself have not risen appreciably. A sufficant rise in pH has resulted from the regular addition of fertilizer to the water, commencing in the spring of 1950. Apparently much of the added phosphorus is being held at a subsurface level by the mud, and may be returned very slowly to the surface layer.

8. Plankton Investigations.

Phytoplankton studies began in 1938. The taxonomic study of the diatoms and dinoflagellates is nearing completion. The importance of phytoplankton in the food chain is obvious, as seen in the food value of the diatoms and smaller algae to mullet.

9. Other Investigations.

(*a*) *Fouling by Marine Growths.*—Fouling studies have been continued at points from Rabaul in the north to Eden in the south. The attaching fauna varies from year to year, and so far no pattern has been observed. This work reveals the importation, on ships' bottoms, of fouling organisms from other countries, since these can be recognized when the local fouling organisms are thoroughly known. Such an importation, with disastrous results, is that of the barnacle *Elminius modestus* (presumably from Australia) into Britain, where it has decimated the British oyster. Several importations into Australia have been observed.

The difference between the fauna in two identical powerhouse conduits cleaned fourteen days apart has led to a study of the *periodicity* of settling of fouling organisms. To carry out this work it was found necessary to reduce other activities. The results show that there is a periodicity in spawning and settlement of a number of marine forms, and that this periodicity appears to be related to moon-phase. This correlation explains some of the anomalies observed in paint tests on ships and panels. Presumably a heavy settling of fouling organisms on a ship, just after docking and before the antifouling paint reaches full leaching rate, gives a non-toxic surface for further fouling, i.e. paint tests on ships are affected by docking schedules. Also, from field observations, it would appear that the settlement of one organism reduced the incidence of certain others, so that cleaning of powerhouse conduits might well be timed to allow the settlement of the least objectionable forms.

Considerable interest is being shown by Australian and overseas shipping and paint firms in this fouling work.

(*b*) *Seaweed Investigations.* — The programme planned to cover the biology and distribution of *Macrocystis* was continued. It aims at getting a reliable estimate of the quantity of *Macrocystis* available in Australian waters, of the extent of seasonal and long-term fluctuations in yield of the seaweed and of its products, alginic acid, mannitol, &c., and of the method of regeneration of the plant.

A survey was completed of the *Macrocystis* beds on the east coast of Tasmania, and their area and tonnage were determined for the year 1950, which is reported to have been a very productive year. Estimates of harvest and yield for 1951, when complete, should give a very rough estimate of the size of the industry which could be based on *Macrocystis* in Tasmania. A more prolonged study will, however, be necessary to determine the extent of long-term productivity fluctuations. Biological studies on *Macrocystis* are being made to determine the effect on the regeneration of the plant of cutting at various levels, the rate and mode of regeneration, and the life history.

Monthly analyses of the seaweed are being carried out to determine seasonal variation in alginic acid and mannitol. Apparently there is little or no laminarin in *Macrocystis.*

Some preliminary experiments were conducted in conjunction with the Division of Forest Products on a process for making a wall-board from *Macrocystis* and sawdust. A large demand for the weed is desirable to encourage large-scale and low-cost harvesting. Australia's requirements for alginate alone are approximately 200 tons per annum, requiring about 800-1,000 tons of dry *Macrocystis* or less than 10,000 tons of the wet weed. On a basis of 10 tons per acre this would require only 1,000 acres, whereas beds are known which cover several square miles, notably in Oyster Bay (Maria Island) and the Acteon Islands.

XII. FOOD.

1. General.

The Organization's research on food processing, preservation, and transport is undertaken chiefly by its Division of Food Preservation and Transport with main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane (meat investigations), West Gosford, New South Wales (citrus fruits), Eden, New South Wales (fish), and the Biochemistry Department, University of Sydney (physical chemistry). The work of the Division is described in Sections 2-12 of this Chapter. Work on the drying and processing of vine fruits is undertaken by the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria (*see* Section 13 below). Co-operative investigations on wines are housed in the Waite Agricultural Research Institute (Section 14). Work on problems relating to the manufacture of dairy products is carried out by the Dairy Research Section at Fishermen's Bend, Victoria, and is described in Section 15 of this Chapter.

Division of Food Preservation and Transport.—Close co-operation between the Division of Food Preservation and outside organizations has always been important in the development of food research in this country. During the year under review co-operative work has been inaugurated in several new fields.

One notable development has been the inauguration of a Plant Physiological Research Unit under the joint auspices of C.S.I.R.O. and the Botany School, University of Sydney. This research unit, which will be supervised jointly by the Senior Lecturer in Plant Physiology at the University and the Principal Plant Physiologist of this Division, will be concerned primarily with problems of plant cell physiology and biochemistry. Not only will this extend the facilities and accelerate the progress in the background research necessary for fruit and vegetable storage work, but it will also provide suitable training in those fields of research for recent graduates.

During the year the Division's Physical Chemistry Group moved into laboratories in the Biochemistry Department, University of Sydney. The move has resulted in fruitful co-operation with Professor J. L. Still and his staff, and has enabled C.S.I.R.O. officers to begin some new lines of work.

The work of the Division has revealed the need for the investigation of many engineering problems in the food industries, but the Division has neither the facilities nor the specialist staff needed for efficient work on most of them. It is hoped that a number of these problems will be investigated in the next few years by research students in the Chemical Engineering Department of the New South Wales University of Technology, working under the direction of Professor J. P. Baxter and his staff. Work on one such project has already begun. Officers of the Division will co-operate with the workers in the University of Technology in the planning of these projects and, if necessary, in some parts of the experimental work. Apart from the technical information obtained, these projects should be of great value in producing men with the training and outlook which will enable them to do useful and urgently needed work in Australian food industries.

Dairy Research Section.—As export of dairy products from Australia is diminishing, and local demand threatens to catch up within a few years with total dairy production, the problems of dairy manufacture alter a little in emphasis and in scope. The problem of the keeping quality of butter, on which much scientific and practical information has been gained by the Section in the past, becomes of even greater importance as prolonged cold storage of butter within Australia is now necessary to meet the winter demand. The need to make use as human food of all the milk produced in Australia, by finding suitable food forms for skim-milk solids and by other means, becomes more pressing. The demand for a greater variety of milk products on the local market is calling for a corresponding diversification of the applied work undertaken by the Section.

The Dairy Research Section has continued to co-operate in its applied studies with the State Departments of Agriculture. In its more fundamental work it has received assistance from the universities and from several sections of the Division of Industrial Chemistry. The Chemical Engineering Section of the Division of Industrial Chemistry has given valuable assistance in providing and operating pilot plant. Investigations on the formation and properties of casein gels, carried out by the Veneer and Gluing Section of the Division of Forest Products, are reported in Chapter XIII., Section 8 (*b*).

2. Physics of Transport and Preservation.

(*a*) *Rail Transport.*—One of the main objects of the rail transport investigations is to discover the principles governing the performance of refrigerated and ventilated cars so that the effects of changes in design and operation may be predicted with sufficient accuracy for practical purposes. Most of the refrigerated rail cars in use in Australia have basket bunkers mounted at the ends and, until recently, work was limited to this type. With an old vehicle borrowed from the New South Wales Government Railways, a detailed study of the performance of end bunkers as coolers was carried out and has led to a much clearer understanding of the way in which end bunkers work and to the formulation of approximate equations believed to be adequate for most practical calculations. A road test carried out in collaboration with the New South Wales Government Railways with cargoes of chilled beef showed very good agreement between calculated and measured cargo temperature histories. A statement on the principles governing the use of these vehicles for chilled beef transport has been prepared in collaboration with the New South Wales Railways.

An experiment carried out in collaboration with the Queensland Department of Agriculture showed that the performance of bunkers could be impaired by stowing cargo in a manner not very different from some commercial practices. Further study of the stowage methods used with some fruit and vegetable cargoes is planned for next summer.

The first of a series of new cars, with roof tanks instead of end bunkers, came into service in New South Wales recently. The Division collaborated with the New South Wales Government Railways in a road test of this car with a cargo of frozen beef. The results were very satisfactory. A good deal remains to be done to clarify the principles governing the performance of these vehicles and so determine the best ways of using them for particular cargoes and journeys.

(*b*) *Canning Processes.*—An account of the work on the evaluation of canning processes mentioned in previous reports has now been published. Some Japanese data on the cooling of cans in air and water have been analysed and heat transfer coefficients different from those given by the Japanese workers deduced. A letter summarizing the results has been published.

Thermocouples are generally used for measuring heat penetration into cans of food during processing. There are several possible sources of error in the readings of these thermocouples, and these are being

investigated. The results will, of course, be applied to other temperature measurements, e.g. in the roasting or freezing of beef.

(*c*) *Sol-air Thermometers.*—The effect of solar radiation on the heat flow into insulated structures must often be considered. It has become common practice to use instruments called sol-air thermometers to measure what may be described, somewhat loosely, as the maximum temperature a surface can reach as the result of the balance between solar radiation and heat loss to the surroundings. An investigation of the effect of some details of design on the readings of such instruments is almost complete.

(*d*) *Water Relations of Dried Fruits.*—Information on the equilibrium humidity of dried fruits at different water contents is required in the industry. Data have been obtained for some dried vine fruits and also for sugared apricots and peaches.

(*e*) *Vapour Pressure Measurements.*—The study of vapour pressure isotherms by the direct measurement of vapour pressure has been continued. It has been found that data on silk protein are of use in identifying the type of protein.

(*f*) *Measurement of Air Flow.*—Because it is difficult to obtain suitable instruments for measuring air flow in drying tunnels, a heated thermocouple type of anemometer has been constructed for trial in the meat drier.

(*g*) *Measurement of Temperature.*—The portable potentiometer which is used extensively in field work cannot be operated on moving vehicles because it is too difficult to balance the galvanometer. An electronic substitute for the galvanometer was therefore designed in collaboration with the Division of Electrotechnology, and the first model constructed has proved very satisfactory for transport investigations.

(*h*) *Evaporation from Stored Fruit.*—The relation between the rate of evaporation and the drying potential of the storage atmosphere has been studied for pears with humidity control apparatus using saturated solutions. The equipment in use is being redesigned in order to obtain more accurate measurements next season.

(*i*) *Freeze Drying.*—The performance of a freeze drier has been studied during a number of test runs. Satisfactory samples of dried apricot and peach purées have been prepared for chemical analyses.

(*j*) *Cool Store Survey.*—The first phase of this survey, the study of temperature distributions in fruit stores, is almost complete and a general report is now being prepared. The survey showed no important consistent differences in performance between different types of store used for long storage of pears. Variations in details of design within the main types in use are much more important.

During the past season attention has been concentrated on cannery cool stores. These present special problems because they are usually filled rapidly and very fast cooling of the fruit is desired.

In canneries pears are generally ripened in the storage rooms. It is often desirable to ripen the fruit in a room so uniformly that it can all be removed for canning on one day, but this uniformity is hard to achieve. Officers of the Division co-operated with the staff of a cannery and with officers of the Victorian Department of Agriculture in ripening trials in a room heated by steam pipes on the floor.

3. Food Chemistry.

(*a*) *Anaerobic Destruction of Ascorbic Acid (Vitamin C).*—The studies on the anaerobic destruction of ascorbic acid are related to the loss of ascorbic acid from canned foods in which virtually anaerobic conditions are established within a short period after canning. The destruction is being studied at 30° C. and pH 2.2–6.0 in citrate-phosphate buffers alone and with the addition of fructose, sucrose, and fructose-1, 6-diphosphate. The added substances have all been shown to increase the destruction at 100° C.

At 30° C. the influence of these factors on the rate of destruction was generally similar to that at 100° C. The rate was a maximum at pH 3-4 and was increased by the added substances, though not so markedly as at 100° C. Approximately the same rate of destruction was found in orange juice and in a citrate-phosphate buffer of similar pH and sugar content.

(*b*) *Natural Coating of Apples.*—The studies on the natural lipoid coating of apples are related to the physiological behaviour of stored fruit, as the natural coating is the main barrier to gaseous diffusion and hence influences the composition of the internal atmosphere. The investigations are concerned mainly with the oil fraction, which increases most markedly during storage. It consists predominantly of unsaturated esters, and the investigations are directed towards the identification of the fatty acids and alcohols.

Much time has been devoted to the assembling of apparatus for low-temperature crystallization of the fatty acids and fractional distillation of their methyl esters. The technique of "amplified" distillation and identification of fatty-acid fractions in the presence of mineral oil has been investigated and most of the difficulties overcome.

The nature of the constituents produced during the increase of oil content has been investigated in more detail. The flesh has been examined for lipoid constituents. Small amounts of soluble lipoids have been found but no material corresponding to the insoluble "cutin" of the skin has been found in the flesh.

Two papers have been prepared for publication.

(*c*) *Volatile Products of Apples.*—The organic volatile substances produced by fresh apples are concerned in the aroma and probably also in the control of ripening. There is evidence of some relation between volatile substances and superficial scald, a functional disorder.

The fatty acids and alcohols have been shown to be predominantly simple and saturated with chain lengths of one to six carbon atoms. The production of volatile esters has been determined quantitatively and a paper has been prepared for publication. Tests have given no evidence that any of these substances are concerned with scald, and attempts are now being made to identify other substances both from apples and from used oil wraps (which are used to control scald). Work on the volatile carbonyl substances has included chromatic separation of the 2,4-dinitrophenylhydrazones.

(*d*) *Physical and Protein Chemistry.*—Changes in the proteins are of great importance in frozen fish, meat, and other products. Rather elaborate biophysical equipment is needed for the study of these changes and much time has been spent in the past year in the design, procurement, and installation of this equipment. The laboratory is now equipped for certain microchemical work, A.C. and D.C. polarigraphy, and potentiometry, and equipment for electrophoresis and infra-red spectroscopy is being set up.

(*e*) *Amino Acid Metal Complexes.*—There is now a considerable body of evidence to show that the combination of amino acids and proteins with metals is important in many biological processes. An investigation has been made of the combination of a number of amino acids and polypeptides with the metals lead, cadmium, copper, and zinc using the technique of D.C. polarography. This study has confirmed the order of stability of metal complexes found by other workers

using different techniques. Attempts are being made to confirm the Bjerrum theory of stepwise formation of the complexes. Recently attention has been directed to the coloured complexes with iron formed by conalbumin, a protein of eggs.

(*f*) *The Determination of Lead in Foods.*—There is no simple, reliable method for the determination of lead in canned foods. A method is being developed based on dithizone extraction, reversion, and polarographic determination of the lead.

(*g*) *Infra-red Spectra of Proteins.*—Protein denaturation is accompanied by structural changes in the protein. An attempt is being made to increase our knowledge of these changes by observing changes in the infra-red spectra of the proteins.

(*h*) *Chemical Reactions in Processed Foods.*—This is a new project begun in the second half of 1950. The reactions selected for the first series of investigations are those which produce brown colours in dehydrated fruit and vegetables during storage. This type of discoloration occurs in many processed foodstuffs and it is likely that several different types of chemical reaction are involved. Dehydrated fruit was considered to be a suitable material for the initial studies since browning can be made to occur rapidly under relatively mild conditions. Preliminary investigations have been carried out with sugared and dehydrated fruit, and attention is at present being concentrated on certain aspects of the chemical composition of the raw fruit. Chromatographic methods are being applied to the identification of the soluble constituents of the fruit. Considerable progress has been made in identifying the members of one important class of compounds in several types of fruit.

4. Microbiology of Foods.

The microbiological research programme is designed to obtain a better understanding of the way in which various environmental factors affect the growth and death of micro-organisms in food. Such information may form a basis for improved methods of food processing or storage.

(*a*) Clostridium botulinum *Investigations.*—Studies of the temperature relations of this important food-poisoning organism have been continued. In addition to the work on types A and B, recent studies have also been made with some type E strains, this being the other toxin type to which man is susceptible. Two papers on the thermal destruction of the toxin have been published.

(*b*) *Heat Resistance of Bacterial Spores.*—The investigation of factors affecting the germination of heat-treated spores was continued, inhibition of germination by small concentrations of saturated and unsaturated fatty acids being studied with both *Clostridium* and *Bacillus* spores. Some important effects have been observed although the reason for them is still unknown. Two papers covering the results of earlier experiments have been published.

(*c*) *Water Relations of Bacteria.*—This project is being developed more actively now that more precise methods for determining the availability of water in bacteriological media are available in this laboratory. Experiments with representative strains of both food poisoning and spoilage organisms have been commenced; greatest attention is being given to the food-poisoning group, for which the information is more urgently required.

(*d*) *Mould Growth Studies.*—The mould previously reported as being unusually well adapted for growth in dry environments has been provisionally identified by an officer of the New South Wales Department of Agriculture as belonging to a new genus. The name *Xeromyces bisporus* has been proposed. The growth of five other moulds isolated from relatively dry materials is now being studied in relation to temperature, pH, and the availability of water.

(*e*) *Mould Wastage of Stored Fruit.*—Work on apple rots caused by *Gloeosporium album* has been continued by an investigator located in the Botany Department at the University of Melbourne. Although it is known that this rot is initiated before the fruit is harvested, it has not been possible to find the fungus in the orchard, or to increase the incidence of rotting by spraying fruits with conidia at various times prior to picking. Investigations in co-operation with the Victorian Department of Agriculture are continuing.

As certain fungi liberate diffusible toxins which destroy the host tissue outside the zone in which the fungus is actually growing, a study has been commenced of the action of *Sclerotinia sclerotiorum* toxin on carrot tissue. This fungus liberates a potent toxin and a study of its effect on carrots has been undertaken because more is known of the physiology of normal carrot tissue than of most fruits. Crude samples of the toxin have been found to promote the loss of several constituents from the host cells. As an aid to the study of these changes quantitative procedures for organic acid analysis by chromatography have been developed, and some aspects of the physiology of carrot tissue have been studied in conjunction with the Department of Botany, University of Melbourne.

Investigation of the surface microflora of oranges from Gosford, New South Wales, has revealed a positive correlation between the level of infection by *Penicillium* sp. and the amount of rotting caused by this fungus.

(*f*) *Bacteriology of Frozen Eggs.*—One hundred samples of frozen egg manufactured in South Australia were examined for the presence of *Salmonella* organisms.

(*g*) *Spoilage of Canned Foods.*—An outbreak of spoilage due to thermophilic bacteria was investigated in a commercial cannery and the principal source of the spoilage organisms determined.

5. Meat.

(*a*) *Co-operative Frozen Beef Studies.*—(i) *Techniques.*—The development of techniques for the determination of quality of frozen and chilled beef carcasses has been continued. The best conditions for preparing a sample of frozen meat for determination of "free drip" have been established and the work is now being extended to the determination of "loaded drip".

A tasting panel has been trained and the performance of the panel as a whole and of its individual members has been studied statistically.

Consideration has been given to the possible errors arising in the estimation of temperatures by thermocouples in meat during chilling and freezing and also in cooking. This matter will be investigated further in collaboration with the Physics Section.

(ii) *Frozen Storage Experiment.*—Paired sides of carcasses have been placed in storage at 8 and 0° F. Examinations at three months and six months have been made and the results for three months analysed statistically. The only difference noticeable after three months' storage was in the weight loss during storage, which was considerably less in the carcasses at 0° F.

(iii) *Carcasses for Study at the Low-temperature Research Station, Cambridge.*—One consignment of selected carcasses covering a range of grades has been shipped for study in England.

(iv) *Chilled Beef Studies.*—Equipment for the determination of CO_2 in the chill rooms by thermal conductivity methods has been installed. Studies of the level of bacterial contamination at two abattoirs have been made preparatory to carrying out experiments to compare chilled with frozen storage.

(*b*) *"Drip" Investigations.*—Large differences between the percentage "drip" from neighbouring muscles and also from various commercial cuts of meat have been found in a storage experiment. They are being studied in relation to the shape and composition of cuts and the pH and fat content of the muscles.

(*c*) *Muscle Biochemistry.*—Methods for the estimation of glycogen and lactic acid in muscle and liver have been checked. The variability of glycogen from point to point within selected muscles is being studied as a preliminary to following the course of glycolysis in ox muscle as affected by pre-slaughter treatment. Methods for the control of steers during pre-slaughter treatment are being worked out. These studies will be carried out in conjunction with work by the Physiology Department of the University of Queensland on the effect of such treatment on the adrenal system. A check has been made of the method of determination of ascorbic acid in adrenal glands.

(*d*) *Air-borne Contamination.*—A study is being made of the normal decay rate of three organisms when sprayed as a mist into a cold room held under various conditions. It has been found possible to account quantitatively for all the organisms supplied to the spraying device. Losses have been quantitatively distributed between losses in spraying and sampling devices, precipitation on surfaces, and death of the organisms. The effects of nature of organism, growth conditions, nature of nutrient medium, and physical conditions within the room on the rates of loss are being determined.

(*e*) *Technique of Estimation of Bacterial Counts.*—As a necessary part of the work on air-borne contamination a study has been made of the effects of blending bacterial suspensions and contaminated meat and of the difference in plate count obtained from meat surfaces using a blender as compared with grinding with sand.

(*f*) *Ozone Studies.*—The study of the dynamics of the ozone system has been extended by measurements of the rates of ozone absorption by meat as affected by size and thickness and nature of the meat slice and the extent of previous ozone treatment. The effect of a relatively high continuous ozone concentration (10 p.p.m.) on the development of a series of organisms is being studied, and will be followed by studies at lower ozone levels and other temperatures and humidities.

(*g*) *Freezer Burn Studies.*—The nature of the removal of water from offal which is associated with freezer burn is being studied. Special attention is being paid to the weight losses before and during freezing and the effect of rates of freezing on the moisture loss. Freezing in mercury is being used to obtain high rates of freezing.

6. Fish.

(*a*) *Survey and Advisory Work.*—Advice and practical help have been given to prawn processors on the North Coast of New South Wales, to canners whose interest in the canning of tuna was stimulated by the visit of the American tuna clipper *Senibua,* and to numerous persons seeking to establish fish processing facilities.

A report on the New Guinea-Papua fish preservation survey conducted early in 1950 was submitted to the Department of External Territories.

Several species of South African fish are closely related to species of commercial importance in Australian waters. Canned packs have been exchanged between Australia and South Africa, and a survey of samples from South Africa has been completed.

(*b*) *Objective (Chemical) Methods for Estimation of Spoilage.*—Considerable work has been done on the development of rapid laboratory and field methods for estimating the degree of fish spoilage. The methods will be used to study the chemistry of flavour changes which occur in some species of fish during canning.

(*c*) *Prawn Investigations.*—It has been found that the development of black staining during storage and transport of cooked prawns can be minimized by strict adherence to a recommended scale of cooking times and storage temperatures. The nature and cause of the stain are being investigated.

(*d*) *Fish Freezing.*—Studies are proceeding on the change of protein structure during freezing of fish.

7. Eggs.

(*a*) *Effects of Shell-coating Treatments.*—Studies on the effects of various shell coatings (particularly mineral oils) on the rate of deterioration of eggs during storage were continued.

The storage investigations using various mineral oil coatings have now been completed and the results will shortly be compiled for publication. With the exception of considerably reduced weight losses, there appear to be no consistent advantages in the use of oil coatings. Occasionally during storage at 68° F., and less frequently at 32-34° F., oiling results in a reduced tendency of the yolks to break when the eggs are opened and also in slightly better flavour than in the untreated eggs. These variations cannot yet be correlated with the physical and chemical factors studied.

One effect of coating with oil is to restrict the loss of carbon dioxide from the egg, thereby leading to accumulation of this gas equivalent to storage in atmospheres containing up to 3 per cent. carbon dioxide. Since several workers have stated that the effects of oiling on the rate of deterioration during storage are due to this accumulation of carbon dioxide, storage experiments at 68° F. were carried out to compare rates of deterioration in oiled eggs and eggs stored in 0.4, 0.9, 3.6, and 9.2 per cent. carbon dioxide. The results showed some correlation between the rates of deterioration in oiled eggs and in the corresponding lots at similar carbon dioxide tension (0.4 and 0.9 per cent.). The experiments will be repeated at lower storage temperatures.

Storage experiments were carried out using a commercial casein-formaldehyde coating which was found to be inferior in performance to oil coating.

(*b*) *Rheological Studies on Thick White.*—For the maintenance of good quality, it is desirable that the thick white should remain firm and large in volume. During storage, however, there is usually a considerable decrease in volume and firmness. No satisfactory methods for the measurement of the change in firmness of the thick-white gel are available, and therefore a study of the rheology of the thick whites from fresh and stored eggs has been undertaken with a view to devising a suitable quantitative method.

(*c*) *Sizes of Export Eggs in Relation to Filler Sizes.*—At the request of the Australian Egg Board, measurements were made of length, maximum diameter, and weight of eggs in each of the main weight grades in the export pack (12, 14, and 16 lb.) in three States. Over 60,000 eggs were measured and the data analysed in relation to the current sizes of filling material used for packing. A final report has been given to the Australian Egg Board, recommending changes in the sizes of the filling materials for the 12 and 14 lb. packs.

(*d*) *Disorders in Eggs Following Ingestion of Malvaceous Plants.*—Ingestion by hens of seeds and leaves of Malvaceous plants causes the onset of pink whites and other disorders in stored eggs. Chemical studies have been begun with a view to isolating and identifying the active principle which occurs in the ether extract. The activity of various fractions of the oil of *Malva parviflora* is at present being investigated.

8. Fresh Fruit and Vegetable Storage and Transport—Plant Physiology and Biochemistry.

Work on the physiology and biochemistry of fruits and vegetables has been continued, with particular reference to the behaviour of cells and tissues. As before, this work is largely concerned with the way in which plant cells accumulate substances from their surroundings and prevent them from diffusing outwards. Simultaneously, the problem of respiration by which the individual cells obtain their energy for continued survival is being investigated.

(*a*) *Salt Accumulation.*—Some progress can be recorded in the study of salt accumulation in its relation to respiration. A paper incorporating observations on 2,4-dinitrophenol, which inhibits salt accumulation without inhibiting respiration, is in the press. A paper on the relation of salt accumulation to the enzyme cytochrome oxidase has been published in collaboration with a member of the staff of the Botany School, University of Melbourne. Following this work, the relation between salt accumulation and respiration has been investigated further, both by the use of substances which will possibly stimulate the transfer of energy from respiration to accumulation and by attempts at isolating the enzyme systems of respiration and making them function outside the cells. The enzyme systems, cytochrome oxidase and succinic dehydrogenase, have been isolated from both beet and carrot tissue and work is continuing to obtain isolates which show the other enzymes concerned with respiration. This work follows that done by animal biochemists, which shows that the respiration in animal tissues is largely confined to small particles—mitochondria—in the cells; these particles are just on the limits of ordinary microscopic visibility. A comprehensive review of the work on salt and respiration was prepared for publication.

(*b*) *Apple Investigations.*—Investigations of nitrogen metabolism have been continued with particular reference to the probable method of synthesis of protein in developing apple tissue. The technique of paper chromatography has been used to study the amino acids from which proteins are synthesized. The free amino acids have been examined in samples of apples from the time of blossom until after normal commercial maturity and have been compared with the amino acids present in the proteins of the same samples. Samples have also been taken from the leaves of the same tree.

The course of development of apples on the tree, which has such a profound effect on their subsequent behaviour, has been investigated further. Samples analysed monthly from time of blossom until the fruit could no longer be held on the tree have confirmed the principal conclusions of work in earlier seasons, which has now been published in two papers, one dealing with the anatomical and the other with the chemical changes. The recent work has extended our knowledge by showing, among other things, that there is a very large influx of soluble nitrogen compounds if the fruit is left on the tree for longer than normal.

Collaborative work with the Division of Plant Industry, aimed at distinguishing the physiological and anatomical differences between light and heavy crop fruit, has been continued at Hobart, Tasmania.

(*c*) *Climacteric Rise in Apples and Bananas.*—The sudden rise in respiration which accompanies ripening in a number of fruits and is known as the climacteric rise, has been investigated in apples and bananas. Considerable work has been necessary to obtain satisfactory techniques for supplying substances in solution to these tissues while the respiration is being measured.

9. Fresh Fruit Storage and Transport—Technology.

Some of the long-range problems of fruit and vegetable storage have been continued and some comparatively short-range projects have been concluded.

(*a*) *Skin Coating.*—Four papers on the extensive work on the use of wax or oil layers applied to the skin of apples have been prepared for publication. They deal with physiological effects of coating, coatings in cool storage, coatings in common storage, and comparisons between coatings and gas storage.

(*b*) *Orchard Variability.*—The experimental work on the variability in storage behaviour in the apple varieties Delicious and Granny Smith, from two orchards in the Orange district, New South Wales, has been concluded after five successive seasons' work. The fruit was kept in cool store for a standard time under standard conditions and was subsequently examined for storage disorders, comparing fruit of different sizes within trees, between trees, between orchards, and between seasons. Statistical work to analyse the results of these experiments is in progress.

(*c*) *Maturity—Number of Days.*—The experiment to determine whether the number of days from full blossom could be used as the best criterion of maturity for picking apples has been concluded. Statistical work is being carried out to analyse the significance of the result, but it would appear that this criterion is not as good as the usual ground colour recommendation for picking as used in most districts of Australia.

(*d*) *Stone Fruits.*—Work on the storage qualities of new varieties of peaches and plums grown on the Bathurst Experimental Farm has been continued this year.

(*e*) *Pear Storage.*—Work on two aspects of pear storage has been continued. The effects of delay and rates of cooling on the storage life and respiration of both William Bon Chrétien and Packham's Triumph varieties have been investigated. Preliminary results seem to indicate that the delay before cooling after picking is not as deleterious to the subsequent storage life of the latter variety as has previously been thought. The other project has been concerned with an investigation of the safe limits of carbon dioxide concentration in the gas storage of Winter Cole pears which have, in recent years, been shown to be more susceptible to the disorder, brown heart, caused by carbon dioxide, than had previously been suspected.

(*f*) *Lemon Storage.*—Work on lemon storage has been continued at the Citrus Research Laboratory at Gosford. It has been established that good tree vigour is necessary for fruits kept for long storage. Treatment with borax and wax will satisfactorily control development of the common green mould, but most loss in storage has been due to stem-end rot. Considerable improvement has been obtained by the use of 2,4-dichlorophenoxyacetic acid applied as a post-harvest dip. This was more successful than pre-harvest spray programmes with either Bordeaux mixture or 2,4-dichlorophenoxyacetic acid.

(*g*) *Orange Storage.*—Experiments at the Gosford laboratory on orange storage showed that the treatment of fruit with a borax-boracic acid mixture followed by waxing has been very successful in control of green mould (*Penicillium digitatum*). Fruits in commercial lots which had been processed in this way were sold on the Sydney markets and received favorable reports from buyers. Following this work recommendations were made to packing shed representatives in Gosford and have been adopted by certain of the sheds. Experiments were carried out with both Navel and Valencia oranges and are to be continued in the coming citrus season.

A number of new fungicides have been tested, but nothing better than the recommended borax treatment has yet been obtained. Mycological tests are being conducted in collaboration with the Microbiological Section of the Division and the Biological Branch of the New South Wales Department of Agriculture. Some interesting relationships between spore load and mould development have been obtained.

(*h*) *Brown Rot.*—Because of the importance of brown rot in apricots and peaches which are stored for subsequent processing, particularly in canning factories, a study of the effect of temperature on the growth rates of both organisms in the fruit was carried out. The results relating growth to temperature have been made available to officers of the New South Wales Department of Agriculture, who are studying the effect of altered methods of handling after picking to reduce the losses in the field.

(*i*) *Fruit Fly.*—The specially designed room for the vapour heat treatment of fruit as a means of destroying fly eggs or larvae which may be in the fruit at time of picking, has been completed and is installed in the Gosford Laboratory. Test runs on controlled temperature and humidity have shown that the equipment is satisfactory and experiments have begun to study the effect of this treatment on the subsequent keeping quality of the fruit. Later, in collaboration with the entomologists of the New South Wales Department of Agriculture, the effect of treatment on the fruit fly will also be examined. Further work on the low-temperature treatment, which kills the fly after some days, was retarded this year because of the shortage of material which had been stung by fly.

(*j*) *Potato Storage Trial.*—Experiments on the storage properties of new varieties of potato being tested by the New South Wales Department of Agriculture have been carried out. These trials have included examination for condition and culinary quality after five months' storage. The culinary tests have been carried out in collaboration with the Dried Foods Section. Some anti-sprout treatments in storage have also been tried.

(*k*) *Papaw Ripening.*—An experiment was carried out to compare three temperatures of ripening at high humidity. It was found that the highest temperature reduced ripe rots but also reduced quality.

(*l*) *Storage for Canning.*—Two experiments have been done in collaboration with the Canning Section. The effect of temperature on the post-harvest changes in canning quality of asparagus was investigated, and two methods of storing J. H. Hale peaches for canning were compared.

10. Canning and Fruit Products.

(*a*) *Vegetable Canning.*—Pea canning investigations were continued on an expanded scale at Devonport, Tasmania, mainly on rate of maturation of commercial crops and determination of correct picking maturity with reference to quality and economy. Physiological changes were followed with the aid of the maturometer and the data obtained were related to tenderometer readings.

Confirmation was obtained of the theoretical conclusion that the maturometer reading of a mixed size grade sample is the mean of the readings of its component parts, weighted in accordance with the number of peas in each size grade. The mixed size grade reading has been conveniently designated the Maturometer Index, and trends in this value appear to reflect day-to-day progression of maturity in the pea crop. Results from two replicated experiments suggest that, under the conditions of test, crops should be harvested when the Maturometer Index reaches 250. At this point there was a marked decrease in vine weight per acre, and a corresponding saving in haulage costs and viner capacity. In both trials ripening proceeded at approximately ½ per cent. alcohol-insoluble solids per day during the week prior to harvest. This information, if confirmed by subsequent work, may provide a basis for the short-term prediction of the date of harvest.

Thirty-five varieties of canning peas were grown in a series of row trials in an endeavour to obtain one or more varieties equal in yield but superior in colour and in flavour to the standard Canners' Perfection. Varieties showing promising agronomic and canning characters will be carried over into a further row trial at Blayney, New South Wales.

Asparagus spears held at atmospheric temperature showed progressive fibre development, but, when canned at intervals up to three days after harvest, were comparable in quality to freshly canned material. Cool-storage tests at a series of temperatures suggested that spears can be held for two weeks at 45° F. and still give an acceptable canned product. White asparagus was found to be superior to green under these conditions. Continued work on the location of bitterness in canned material confirmed that it is concentrated in the butt of the spear. It occurred in greater concentration in white than in green asparagus, and it is recommended that canned white asparagus should be held for one month before commercial distribution.

Tissue-firming investigations of brassicas were continued. Histological examinations of treated and untreated tissue were made and tests of objective methods of measurement of firmness were conducted.

Officers of the Division have co-operated with officers of the New South Wales Department of Agriculture in a breeding programme of canning and pulping tomatoes involving 40 selected crosses originating at C.S.I.R.O. Division of Plant Industry, Canberra, and at Hawkesbury Agricultural College. Satisfactory progress was made and the work will be amplified in the next season by the inclusion of a number of hybrid types.

Eight stringed and stringless canning bean varieties were tested for quality, agronomic factors, and maturity/yield relationships. Results suggested that the so-called canning off-flavour and stringlessness are related.

(*b*) *Fruit Canning.*—Varietal trials of freestone peaches for canning have been concluded. There is evidence of some variation in quality from season to season. Halehaven, Blackburn, and Success are strongly recommended to processors, and J. H. Hale, Viceroy, Elberta Dripstone, Elberta Cling, Gray's, and Fragar are also classified as satisfactory for canning. Cool-storage tests designed to extend the canning season were conducted with J. H. Hale variety. Results showed that fruit could be stored at 34 and 41° F. for three weeks and then ripened at 68° F. to give a product of good quality.

Chemical investigation of discoloration in canned bananas was continued. It is probable that two separate types of discoloration occur, and their mechanisms are being studied.

Preliminary work on the improvement of canned solid pack apple has been completed. Experiments on a commercial scale are to be undertaken in Tasmania. Recommendations for syrup concentration have been made for packs of apple in syrup.

Minor investigations of problems related to the canning of apricots, oranges, passionfruit, pears, pineapples, quinces, rock melons, and berry fruits were completed.

(*c*) *Fruit Juices.*—Two quality defects which greatly affect the acceptability of canned orange juice were investigated. The first is the bitterness which appears in processed juices from Washington Navel and some

Valencia oranges. Two bitter principles, limonin and "substance X", have been isolated from oranges, mainly from the peel and seeds. The constitution of limonin is not yet known but it has been shown that the reactive groups comprise an isolated ketone group and two lactone groups, probably α,β—unsaturated γ—lactones. "Substance X" is related to limonin as an oxidation product.

A survey of nine orchards in the Gosford district provided further evidence on the occurrence of bitterness in juices from Valencia oranges sprayed with fungicides containing copper. No bitterness was detectable in fruit from experimental plots at Kulnura, thus confirming previous experience that this effect of copper sprays is not evident on young trees.

The second defect in canned orange juice is its instability during storage, which leads to the appearance of "stale" flavours and significant losses of vitamin C.

These detrimental changes in flavour and nutritive value have been generally attributed to oxidation. It has now been shown, however, that the effect of oxygen is small and confined to the first few weeks of storage while free oxygen remains in the can. Thereafter anaerobic reactions continue and are mainly responsible for the quality deterioration in canned orange juice.

The effect of rootstock on the quality of canned orange juice was studied. The results of one season's work indicate that *Poncirus trifoliata* rootstocks with both Valencia and Washington Navel oranges give juices markedly superior in quality to the Rough Lemon and Sweet Orange rootstocks commonly used in Australia. Washington Navel oranges on *P. trifoliata* rootstock appear to give a juice that is free from bitterness at normal maturity.

(*d*) *Container Investigations.*—The present acute tinplate shortage has emphasized the importance of the investigations on electrolytic tinplate containers, which were designed to determine the suitability for Australian canned foods of electrotinplate cans protected internally with lacquers of Australian origin. After nine months' incubation at 100° F., lacquered electrotinplate cans containing peaches, pears, sweet corn, and tomato juice are performing as well as or better than hot-dipped tinplate cans.

The study of improved procedures for assessing can lacquer performance was continued since there is a real need for accelerated tests under present conditions of fluctuating raw material supplies. An electrochemical procedure for evaluating acid-resisting lacquers was found to be particularly effective in detecting fabrication damage to lacquer films. The "kidneys-in-brine" test for sulphur-resisting lacquers was modified to give greater reproducibility.

More than 100 different lacquer treatments have been tested on vacuum caps for glass containers. No treatment can yet be recommended as completely satisfactory for highly acid foods containing sulphur dioxide preservative, but some lacquers based on vinyl resins show considerable promise.

(*e*) *Equipment.*—Performance data were obtained for the thermorotary cooker by continuous measurement of temperature change during heating and cooling phases. The rate of heating was found to increase with increase in rate of rotation in the range 80-180 r.p.m., the latter figure representing the maximum capacity of the cooker. The temperature of liquids of low viscosity such as orange juice was raised from 75 to 195° F. in 80 seconds as compared with 100 seconds for the same temperature rise in vigorously boiling water. The advantage of rotary cooking over the "still" cook for viscous liquids was clearly demonstrated. Tomato purée and pineapple pulp required respectively 40 and 50 minutes "still" cook to reach 195° F. from an initial temperature of 70° F. These times were reduced to 80 seconds and 2.6 minutes under thermorotation.

The thermorotary cooker is mechanically simpler, requires less floor space per unit of output, and is more efficient than existing commercial equipment. Modifications of design to increase efficiency and output are in hand. The design of a pressure rotary cooker for the production of canned vegetables is also receiving consideration.

(*f*) *Service to Industry.*—During the year commercial canned samples covering a wide range of foods were submitted to laboratory examination and report. Inquiries by telephone, letter, and in person amounted to 372 during the same period.

11. Dried Foods.

(*a*) *Vegetables.*—A survey was made of the equipment in a vegetable dehydration factory and the way in which it was being operated, and a detailed report submitted to the management. An outline was also prepared of the buildings and equipment needed for compression and gas packing on a semi-commercial scale.

(*b*) *Fruit.*—At the request of the Dried Fruits Processing Committee bulk samples of dehydrated freestone and clingstone peaches have been prepared. It is intended that this material should be available to industry on request, to demonstrate the quality obtainable by methods recommended by the Committee. It is also intended to prepare samples of dehydrated apricots.

The range of freestone peach varieties which have been dehydrated has been extended and now includes J. H. Hale, Blackburn, Elberta, Success, Viceroy, Halehaven, and Gray's. In the 1950-51 experiments all except J. H. Hale were tested. Halehaven proved best, but all gave a very satisfactory product.

The unique stability of β-carotene in dehydrated apricot has been confirmed. Samples stored at 120° F. for six months, by which time they were jet black, had a carotene content comparable to samples stored at 10° F., at which temperature no deterioration was detectable. It was shown by special analyses that the pigments from both lots were identical with pure β-carotene.

A statement on the dehydration of apricots and peaches was prepared for issue by the Dried Fruits Processing Committee.

(*c*) *Dehydrated Sugared Fruit.*—Additional experiments have confirmed the conclusion that this product has a longer storage life than ordinary dehydrated fruit. The potential storage life of dried fruit is almost entirely dependent on its sulphur dioxide content; about 2,500 p.p.m. are necessary to ensure twelve months' storage life for apricots or peaches. However, when the fruit is impregnated with sugar by steeping overnight in saturated syrup and then dehydrated, only 500 p.p.m. are required to give a storage life of at least twelve months.

The chief factors influencing the quality of dehydrated sugared fruit and its storage life have been demonstrated. They include fruit maturity, composition and temperature of the steeping syrup, and the sulphur dioxide and moisture content of the finished product. Experiments are now in progress to provide more precise data on sulphur dioxide concentrations and syrup composition. The use of low methoxyl pectin as a surface coating to overcome surface stickiness in sugared fruit is being investigated.

One practical problem arising from the necessity, in commercial practice, of re-using the steeping syrups, is the best method of adjusting the composition, concentration, and metabisulphite content of the used

syrup. Another is the effect of long-continued re-use of the syrup on the quality of the product. Investigations have been begun on these related problems.

A statement on the production of dehydrated sugared fruit was prepared for issue by the Dried Fruits Processing Committee.

(*d*) *Medicinal Jubes.*—A request for information on a suitable design of dehydration tunnel for jubes necessitated experimental drying to obtain essential data. Subsequently suggestions were made for the design of a dehydrator capable of increasing the drying rate.

(*e*) *Meat.*—The production of blocks of compressed dehydrated mutton has been studied and it has been shown that under suitable conditions the dried mince can be compressed into blocks without serious impairment of its texture. Improvements have also been made in the equipment and techniques used for gas packing and in the examination of samples after storage.

Compressed blocks and gas-packed samples, prepared by the improved methods, have been used for a comprehensive storage experiment which is still in progress. The results obtained so far indicate that gas-packed samples and compressed blocks keep much better than dried mince packed in tins in the ordinary way.

Dried mince can be served in only a limited number of ways, so that an alternative form of dried mutton would be useful. Consequently work has been done on the dehydration of slices of mutton. Preliminary tests have shown that dried slices of good quality can be produced, but there are serious technical difficulties. The raw material is inherently very variable and the slices vary enormously in physical and chemical composition. It also proved difficult to obtain slices sufficiently uniform in thickness. The effects of slice thickness, cooking time, fat content, and temperature on the drying rate have been investigated and all were found to be important.

12. Frozen Fruits and Vegetables.

Investigations on the freezing of fruits and vegetables are conducted jointly with the New South Wales Department of Agriculture. The work is at present concerned mainly with the testing of local and introduced varieties for their suitability for freezing. The district in which the crop is grown may affect the quality of the raw material and an attempt is being made to compare the same varieties grown in several localities.

Much information on handling, processing, and freezing techniques is available from overseas sources but it is necessary to study these methods under Australian conditions before they can be recommended to the industry.

(*a*) *Fruits.*—The experiments on the freezing of freestone peach varieties have been continued during 1950-51. It appears that a number of commercially-grown varieties are satisfactory for freezing. White-fleshed peaches are not as attractive in appearance as yellow-fleshed varieties but their flavour is generally very good. To prevent browning of the peach slices during freezing and thawing, it is necessary to add ascorbic acid. Further information has been obtained on the optimum concentration of ascorbic acid and on the effect of adding citric acid as well.

Methods of incorporating sugar in frozen fruits have been studied with berry fruits, cherries, apricots, apples, pineapples, passionfruit, and papaws. Different varieties of several of these fruits have been compared and the effect of maturity on the quality of the frozen product has been studied.

(*b*) *Vegetables.*—Peas are by far the most important frozen vegetable in Australia and elsewhere, and more time, therefore, has been devoted to problems associated with this product.

The question of suitable varieties is still under investigation. A number of commercial varieties examined appear to be very satisfactory. Trials have been conducted to determine the best stage of maturity for the harvesting of peas. Methods of predicting and determining the maturity of peas are being studied in conjunction with officers of the Canning Section at Homebush.

The commercial procedure of harvesting, threshing ("vining"), and handling peas before freezing may affect the flavour and texture of the finished product. It has been found that the delay which often occurs between vining and processing has a pronounced effect on the development of off-flavours and of skin toughness. Certain losses of sugar and ascorbic acid may also occur. The extent to which these changes can be controlled by various methods of cooling after vining is being investigated.

Studies on green and white asparagus indicate that frozen green spears give a cooked product which compares well with cooked fresh asparagus. White asparagus is not satisfactory for freezing because of the persistence of the bitter taste. Information has been obtained on losses in ascorbic acid during the freezing and storage of asparagus.

Experimental work on other vegetables—French beans, cauliflower, sprouting broccoli, Brussels sprouts, and sweet corn—has been concerned mainly with variety testing, blanching methods, leaching losses during processing, and changes during storage at 0° F.

13. Dried Vine Fruit.

Investigations on sultana drying were continued at the Merbein Station and at the Nyah-Woorinen Enquiry Committee's experiment vineyard at Woorinen. Work on oil emulsions for use in dipping sultanas by the cold-dip process has been extended to cover a systematic study of the fatty acid esters and sulphated fatty acid esters; it is proposed to investigate later the properties of compounds containing similar paraffin chains attached to other polar groups.

It has been shown that simple alkyl esters like ethyl, butyl, or amyl oleate are much more effective in hastening drying than triglycerides like olive or peanut oils. Sulphated alkyl oleates are usually somewhat less effective than the original esters in hastening drying, but are excellent wetting and emulsifying agents, and these properties are of great value in preparing a satisfactory dipping mixture.

Suitable mixtures of alkyl and sulphated alkyl oleates have given excellent results in drying trials.

This work has materially assisted the development of improved commercial dipping oils, and has resulted in vegetable oils being largely replaced by products prepared from olein derived from animal fats.

Bulk hot dipping of sultanas and gordos has been investigated further. Under the excellent drying conditions prevailing last season, little advantage was gained in drying rate by bulk hot dipping sultanas as compared with cold dipping. It was shown that by suitably sulphuring sultanas prior to bulk hot dipping, "green tinge" could be eliminated while the fruit was drying on the racks, but some difficulty was experienced in controlling the sulphur dioxide content under commercial conditions. Satisfactory results were obtained in the bulk hot dipping of gordos with the 200° F. caustic soda dip.

Substitutes for mineral oil in the packing-house treatment of dried vine fruits were again the subject of investigation. Previous work at the Merbein Station showed that refined vegetable oil, such as peanut oil, can be used if treated with a suitable antioxidant such as "N.D.G.A.". It is proposed to extend this work to include additional antioxidants and other possible substitutes.

Investigations are in progress on the rot-proofing of hessian for use in connexion with fruit drying. Results indicate that the cuprammonium process, copper oleate, pentachlorophenol, copper pentachlorophenate, and D.D.M. all give an appreciable measure of protection against rot.

14. Wine.

The investigations directed by the Committee on Oenological Research, which comprises representatives of the Organization, the Federal Viticultural Council, the Australian Wine Board, and the University of Adelaide, have been continued at the Waite Agricultural Research Institute.

(*a*) *Sherry Investigations.*—The effects of various factors on the changes brought about in wine by the sherry flor yeasts have been further studied. Such changes are the results of both aerobic and anaerobic metabolism, the former usually leading to the accumulation of acetaldehyde in the wine and the latter leading to its removal. Because the development of flor character is associated with the accumulation of aldehyde in the wine, it is controlled by the balance between the aerobic and anaerobic metabolism of the flor film and is influenced by a wide range of factors. The influences of many such factors have now been ascertained and recommendations based on these findings are being applied in the industry with promising results.

Some good-quality flor sherries have been made in the laboratory by means of a percolation column packed with oak chips on which the flor yeast grows. However, after extensive tests it was decided that neither the quality of the product nor the economics of the process made the percolation column more attractive than the traditional cask process under industrial conditions.

Two authentic cultures of flor yeast from Spain have been added to the collection and are being tested in the laboratory and in several wineries.

(*b*) *Wine Yeasts.*—Testing of the yeasts in the culture collection by means of laboratory fermentation trials has been continued and a series of preliminary tests of all the wine yeasts in the collection has been completed. From the results obtained, it is apparent that the yeasts differ considerably in alcohol production and completeness of fermentation. Those strains which appeared most promising in the preliminary trials are now being subjected to more detailed tests.

15. Dairy Products.

(*a*) *The Utilization of Skim-milk Solids.*—Studies on the addition of skim-milk solids to bread have been carried out at the Bread Research Institute in Sydney. Skim-milk contains food elements widely lacking in the Australian diet, and its addition to bread is one of the most satisfactory means of supplying those elements where they are most needed. Although this investigation is not completed, sufficient progress has been made to allow commercial utilization of the findings. Both longer fermentation time and smaller loaf volume, difficulties which accompanied the initial attempts to incorporate skim-milk solids in Australian bread, have been overcome. This has been achieved by drying a skim milk adequately preheated and containing a small proportion of glyceryl monostearate and sufficient potassium bromate to bring the content in the flour near the legal maximum. The salt content in the dough mix is slightly reduced. Costs of milk bread may be a little higher than water bread, but the difference is small in relation to the greater nutritive value, and with appropriate promotion it should be possible to use these research findings to the benefit of the Australian diet.

Of the other possible uses of skim milk as food, attention has been concentrated on the conversion of skim milk to products capable of replacing eggs in some of their more specialized uses. An improved egg-albumen substitute has been developed and tested. Commercial-scale production is to be undertaken shortly. Work is proceeding on the manufacture of a product to take the place of eggs in sponge cakes. It is not anticipated that all the egg can be successfully replaced, but, if the present objective of 50 per cent. replacement is attained, it will give considerable economic gains.

(*b*) *Weed Taints in Butter.*—Studies on weed taint in dairy products have been terminated for the present. Reports on the two major lines of work, the isolation of the substance responsible for *Coronopus* taint and the elucidation of the mechanism of *Lepidium* taint, have been prepared for publication. For neither taint has it been possible, from the understanding we now have of the chemistry of the flavours, to develop methods of avoiding the taints once the cows eat the weeds. Agricultural measures to eliminate the weeds must provide the solution to the problem. At the same time, it is possible, now that the chemistry of the taints is understood, to watch for developments in chemistry or processing technique which may permit removal of the taints from cream or butter fat.

(*c*) *Testing of Continuous Butter Processes.*—Trials of the "New Way" process of butter-making, conducted on behalf of the Australian Dairy Produce Board, were completed and a report prepared for publication. While the general quality of the butter was of a high standard, a tendency to split or crack detracted from its appearance. Keeping quality of the butter was particularly good.

Costs of manufacture by the "New Way" process were a little below those for normal churning.

Close contact has been maintained with the development of other new butter-making processes in the United States and elsewhere.

(*d*) *Oxidized Flavour in Dairy Products.*—With the completion of the report on the effect of light on milk, laboratory studies on the effect of copper on the flavour of milk were undertaken. These have led to similar findings, the resultant oxidized flavour being found to be a blend of flavours produced in the fat and in the non-fat constituents of the milk. In contrast to results obtained in the United States of America, in all cases where the flavour has been affected the butter fat has been found to be both measurably oxidized and altered in flavour. Promising results are now being obtained in the isolation of the substances responsible for oxidized flavour in milk.

Applied studies were also undertaken in this field. In conjunction with the Victorian Department of Agriculture a survey was made of the incidence of oxidized flavours in whole milk as consumed in Melbourne households. A majority of samples was found to be affected in some degree, and in about one-quarter of the samples the flavour was strong. Comparison with samples taken direct from pasteurizing and bottling plants showed that the flavour arose almost entirely from exposure to light during or after distribution. The results have been reported to the milk distributing industry.

(*e*) *Mineral Sediment in Sweetened Condensed Milk.*—Studies on this defect of sweetened condensed milk were completed and a report has been prepared for publication. By the use of low storage temperatures the trouble may be avoided.

(*f*) *Cheese Flavour.*—Preliminary investigations have been made in the isolation and identification of the flavouring substances in Cheddar cheese.

(*g*) *Cheese Starter Cultures.*—An officer has now commenced work on the general problem of providing for the cheese industry in Australia starter cultures which are both reliable and of sufficient activity to

reduce appreciably the total time taken for cheese manufacture. Besides studies of the biochemistry and biology of cheese starter activity, modifications in starter propagating equipment are being undertaken to mechanize as far as possible this part of the cheese-making process and to diminish the chances of bacteriophage infection of the starter cultures. Close contact is being maintained with the State Departments of Agriculture.

(*h*) *Extraneous Matter in Dairy Products.*—The testing of manufactured dairy products for extraneous matter (insect parts, hairs, plant material, &c.) is widely practised in the United States of America and Canada, but had never been undertaken in Australia. With the export of dried milks to North America, and the use of Australian butter in British foods exported to the United States of America, attention has had to be directed to this aspect of cleanliness in our daily products. To provide a general picture of Australian conditions and to develop suitable methods, work in this field was initiated by the Section. The results are being reported to the industry and to those Government Departments which will be concerned with the regular control of extraneous matter.

(*i*) *Other Investigations.*—The relationship between composition of sweetened condensed milk and its refractive index is being determined for milk manufactured to Australian standards. Figures at present available apply only to the American product with a different fat/total solids ratio, and cannot be used in control of composition in manufacture in Australia.

The flavour of tea made with reconstituted dried whole and skim milks has been tested. For use by the Armed Services the skim milk would have considerable advantages in case of packaging and good keeping quality, and would be essentially equivalent in food value.

XIII. FOREST PRODUCTS.

1. General.

To make possible the most effective utilization of Australia's forest resources, the Organization conducts investigations into the properties and methods of treatment of Australian timbers. This work is carried out mainly by the Division of Forest Products, which collaborates with Commonwealth and State forestry authorities and with similar laboratories in other countries.

Work in the Division of Entomology, Canberra, on timber pests is described in Chapter IX., Sections 11 and 13(*d*).

Division of Forest Products.—The work of this Division during the year is outlined in the remainder of this chapter.

The timber industry in Australia has operated at a high level during the year and has met the bulk of the expanded timber requirements, a contribution all the more important in view of the increasing difficulty of obtaining suitable timber from overseas and the greatly increased prices and freight charges entailed. Requests for assistance from the Division of Forest Products have, therefore, been heavier than ever, particularly in connexion with sawmill design and operation, seasoning kilns and plant layout, preservation of timber, the peeling of new species for plywood, and wood waste utilization.

The shortage of durable timbers is being increasingly felt, particularly with sleepers and poles, and in some States pit props, house blocks, and similar material are in short supply. Laboratory and field tests of poles and other round timbers have amply demonstrated that less durable species, properly treated, can give excellent service. Supplies of suitable material for treatment are available, particularly in the regrowth eucalypt forests, so that the main requirement now is the installation of treatment plants at suitable localities.

An important overseas conference held during the year was that of the Food and Agriculture Organization's Forestry and Forest Products Commission for Asia and the Pacific, held in Bangkok in October, 1950. This conference was of particular interest to Australia because the grading and nomenclature of Australian timbers and many timbers imported into Australia were under discussion. Australia was represented by an officer of the Division of Forest Products, who was able to show that many of the standards proposed did not conform to Australian practice and would, in fact, be detrimental to our industry. The proposals arising from two earlier conferences were modified, but the experience has drawn attention to the danger that may result from Australia's not being represented at such conferences and not playing its full part in technical collaboration with countries to its north.

Within Australia the annual Forest Products Research Conference and the annual Pulp and Paper Co-operative Research Conference were again held at the Division's laboratory in October and November, 1950, respectively. The Division was well represented at the Fifth General Conference of the Australian Pulp and Paper Industry Technical Association held at Burnie, Tasmania, in March, 1951, and five papers were contributed. Two officers of the Division attended the Eastern States Timber Industry Stabilization Conference held this year at Healesville, Victoria. In addition to contributing papers, the Division was host to the Conference for a day and a comprehensive inspection of the Division's activities was made by some 80 delegates. Visits to the Division were made by many other groups, including members of the Victorian State Committee of C.S.I.R.O. and the Building Research and Development Advisory Committee. The total attendance at these tours approximated 400, to which must be added the very large number of people who were shown individually the Division's work.

The demand for training in the Division increased appreciably during the year. Two visitors from Thailand are studying plywood manufacture and a U.N.E.S.C.O. Fellow from the Philippines is studying wood structure. Officers of the Forest Services of Malaya and Pakistan returned recently to their own countries after working in the Division, the officer from Pakistan being a U.N.E.S.C.O. Fellow. Another officer of the Malayan Forest Service is expected shortly. Representatives of two large Australian companies have worked in the Division, one studying wood and fibre structure and the other the utilization of bagasse for building boards. An officer of the Queensland Forest Service spent two weeks in the Division investigating the latest developments on preservation, seasoning, and mill studies.

The courses in forest products for forestry and architecture students of the University of Melbourne were continued and 38 students from the Australian Forestry School, Canberra, spent ten days in the Division at lectures and demonstrations. Lectures were also given by officers of the Division at the Victorian Forestry School, Creswick. The demand on the Division for individual lectures was greater than ever and suitable talks were given to professional and technical institutions, colleges, technical schools, branches of unions, and Church groups.

During the year the Division co-operated with the C.S.I.R.O. Film Unit in the manufacture of a 16-mm. film, " Science and Wood ", which shows the equipment and activities of the Division and will be of great assistance for external lectures.

The Division has always received large numbers of inquiries and during the year these increased by some 35 per cent. to a total of approximately 7,000 per year. To reduce interference with research activities an Information Officer has been appointed to supplement the organization already built up for handling requests for information.

The Division provided exhibits for the Royal Show, Melbourne, in September, 1950; the Twentieth Century Mechanical Exhibition in October, 1950; the Centenary and Jubilee Exhibition in March-April, 1951; and the Building Research Display organized by the Building Research Liaison Service, which visited Sydney, Melbourne, Perth, Adelaide, and Hobart and is to visit Brisbane.

The help and co-operation of the paper companies, the Commonwealth Forestry and Timber Bureau, the State Forest Services, the New Guinea Forests Department, and of all branches of the timber and allied industries are gratefully acknowledged. The help given this year by industry took tangible form in providing the funds for an electron microscope which has been placed on order for the Division.

2. Wood Structure.

(*a*) *Anatomical Investigations.*—The continuing study of the anatomy of various timbers from Malaya, Borneo, and New Guinea has proved of considerable value because of the large number of timbers from these regions now entering Australia. A card sorting identification key based on macroscopic features only has been prepared for North Borneo timbers, of which some 160 species have been covered. Of particular interest has been the examination of the anatomy of the new genus *Eucalyptopsis* White, of the family Myrtaceae, and of specimens from New Guinea and Indonesia placed botanically in the genus *Nothofagus*.

(*b*) *Cell-wall and Fibre Studies.*—(i) *Spiral Thickenings.*—Previously reported observations relating the inclination of spiral thickenings in tracheids of Douglas fir to cell length have been confirmed by the examination of specimens of yew; in both species the number of turns of the spiral per cell increased with increasing cell length. The results obtained point to the importance of the cytoplasm in influencing the development both of these thickenings and of the micellar system of the cell wall, which is a major factor governing the properties of the wood.

(ii) *Cell Division in the Cambium—The Formation of Compression Wood.*—It has been shown that the formation of compression wood in conifer stems involves an increase in the number of anticlinal divisions of the fusiform initials resulting in a decrease in the average tracheid length. Similar observations have been made in stems where there has been a sudden change from narrow to wide growth rings. The results demonstrate that at least some of the undesirable properties of compression wood arise from the changed growth rate which accompanies its formation because the increased radial growth rate, through the accompanying changes in cell length, influences micellar organization in the cell walls and thus wood properties.

(iii) *Fine Structure of the Xylem Parenchyma Cells.*—X-ray diffraction, examination of crushed isolated cells, polarization optics, and the examination of material affected by fungal attack have been used to demonstrate that the micellar organization of the secondary wall of these cells is of a continuous spiral nature and that the angle is large in relation to the longitudinal cell axis. In certain species the intercellular material is enormously developed in medullary ray tissue. Extremely thick secondary walls made up of a number of individual layers have been observed in certain parenchyma cells of *Dialium laurium*.

(iv) *Variation in Cell Length.*—Within any one stem it has been found that there is a correlation between cell length and radial growth rate; there is evidence to indicate a similar correlation in different stems of the one species. Thus, in general, a faster radial growth rate is accompanied by a lower average cell length, and a slower radial growth rate by a higher average cell length. This is particularly interesting in view of the fact that cell length within any one stem has been demonstrated to be correlated with certain physical and mechanical properties. Observations have shown that certain trees of a species have a comparatively high cell length in the first growth ring from the pith in comparison with other trees of the same species; moreover, the cell length increases normally at the same rate in both cases so that a tree with a higher initial cell length maintains a higher cell length thereafter. These observations may prove of some value in utilization, because of the demonstrated relation between length and properties, and in the field of pulp and paper manufacture, where high cell length is a desirable feature. Experiments, therefore, are being carried out in co-operation with the Commonwealth Forestry and Timber Bureau to determine the extent of this high initial cell length in various trees of pine. Trees found to be satisfactory as regards both initial cell length and other factors will be used as parent trees.

(*c*) *Structure in Relation to Properties.*—(i) *Sapwood-Heartwood.*—In the continued investigation of the changes which occur when sapwood is transferred into heartwood, attention has been paid to the factors causing the death of medullary ray and vertical parenchyma cells. In a number of selected species representing fifteen genera of different families death of these cells has been shown to be closely associated with the presence of fungal hyphae in the heartwood; in only two genera was a dark-coloured heartwood observed without fungal hyphae being detected. Clusters of crystals of characteristic colour and shape have also been noted in the heartwood of many species and, because of their association with fungal hyphae, their presence is considered indicative of the presence of fungal hyphae. However, although observed to be commonly present in the many species of the genus *Eucalyptus*, the association of these crystals with fungal hyphae in this genus has not yet been definitely established. Chromatographs of the materials extracted from the heartwood and bark of different genera are being studied. In those species in which heartwood is not normally produced, no tannin has been observed in the ray cells of the wood and these cells may be alive to the very centre of large trees. In other species, where the heartwood is found only as a small central area surrounded by a very wide sapwood, the tannin appears to accumulate in the ray cells during the life of the tree and the older ray cells at or near the centre may be filled with such tannin material although there is little present in the cells near the outside of the tree.

(ii) *Thermal Expansion.*—It has been shown that changes in this property occur in successive growth rings from the pith outwards in conifer stems. Variations have been investigated in normal stems, in stems containing compression wood, and in stems which have undergone considerable changes in growth rate. Both shrinkage and thermal expansion depend on the cell-wall organization and vary with changes in cell length.

(iii) *Shrinkage.*—Preliminary results show that variations in shrinkage from the pith outwards also occur in alpine ash, the longitudinal shrinkage being greatest at the centre of the tree and decreasing to the outside. Conversely, the tangential shrinkage was smallest at the centre and greatest at the outside.

These variations are again correlated with cell length and cell-wall organization.

(*d*) *Inorganic Inclusions in Timber.*—(i) *Silica.*—The survey of timber species containing deposits of silica in various cells has been completed and the results brought together for publication. An examination of timbers reported to be siliceous from British Guiana was carried out at the request of the Conservator of Forests. Quite a number of the species submitted belonging to the Rosaceae and Lecythidaceae were found to contain comparatively high percentages of silica. The exact reason for the resistance of siliceous timbers to teredine attack has not been established but work is being carried out in conjunction with the Zoology Department, University of Melbourne, on the mechanism of digestion in these borers.

(ii) *Calcium Oxalate.*—X-ray methods have been used in the examination of the nature and occurrence of calcium oxalate deposits in wood tissues.

(*e*) *Identifications and Identification Methods.*—Identifications made during the year totalled 1150. These included numerous timber species from New Guinea which were examined and classified to assist botanical determinations. A second lot of 100 sets of the card sorting identification key for commercial Australian timbers has been made up and many of them have been distributed. The policy has been adopted of distributing these sets to schools and timber firms where woodworking instructors and others have been taught how to use the key to best advantage. Work has continued on the various timber species of the genus *Eucalyptus* but the revision of identification methods of these species is not yet complete.

3. Wood Chemistry.

(*a*) *Lignin and Related Compounds.*—(i) *Methanol Lignin.*—Paper partition chromatography in various solvent systems has revealed that methanol lignin is heterogeneous in that it contains related materials, such as aldehyde and neutral degradation products, which are adsorbed on the precipitated lignin. Experiments have led to the conclusion that "native" lignin for chemical study would best be isolated by a method involving chromatographic purification.

(ii) *Aldehydes from Eucalypt Lignins.*—The aldehyde mixture from nitrobenzene oxidation of eucalypt woods contains, in addition to vanillin and syringaldehyde, a third methoxyl-free aldehyde in smaller amount. This aldehyde has been isolated by a solvent extraction method, purified in a "chromatopile", and identified as *p*-hydroxybenzaldehyde. Separation of the latter from vanillin and from syringaldehyde by counter-current distribution methods has been effected in accord with theoretical predictions.

(iii) *Methylation of Methanol Lignin.*—Control experiments on substances of known constitution have shown that the choice of solvent can affect the yield and nature of the products of diazomethane methylation. Methylation of methanol lignins obtained at various stages has resulted in variable methoxyl contents.

(*b*) *Polyaldouronide Associated with Lignin.*—Conditions for the extraction and recovery of polyaldouronide from methanol-cooked mountain ash (*Eucalyptus regnans*) wood have been determined experimentally, and the most suitable extraction is with water at room temperature over a period of 24 hours. The extract may be concentrated under vacuum without degradation provided that the temperature does not exceed 40° C. Precipitation from a neutral unconcentrated solution requires an eight-fold quantity of 99 per cent. ethanol. Best results have been obtained at pH of *c.* 3.7 in 80 per cent. ethanol.

(*c*) *Wood Hydrolysis.*—Hydrolysis experiments in a percolator in 2 per cent. sulphuric acid at 160° C. have shown that normal wood of mountain ash hydrolyses more than twice as fast as does tension wood, thus confirming that all the cellulose in tension wood is more highly orientated than in normal wood. There is also much more resistant cellulose in tension wood. Early wood and late wood of mountain ash hydrolyse at approximately the same rate. No systematic trends have been revealed in the rates of hydrolysis of butt, centre, and top log samples from the outer heartwood zones.

(*d*) *General Wood Chemistry*—(i) *Representative and Reproducible Samples for Chemical Investigation.*—Statistical investigation of the analytical data on 30 samples collected under this project has shown that the species sample was adequate for estimating the required size of future sampling programmes for mountain ash. The data have been used to prepare curves from which may be calculated the number of trees required for a reproducible sample whose "species" mean for a particular chemical property is within chosen limits. The procedure has been laid down for collection of a sample which will be representative of the species.

(ii) *Chlorite Holocellulose.*—Investigation of the influence of temperature and chlorite dosage on the holocellulose determination has led to the development of a two-stage method which will give satisfactory and reproducible results. The optimum temperature is 70° C. The first stage of the method involves treatment with 120 per cent. sodium chlorite over 2 hours. The chlorite dosage in the second stage varies from 40 to 120 per cent., and the time from 3 to 5 hours, making the total time for the analysis from 5.5 to 8.5 hours depending on the lignin content of the wood.

(iii) *Colorimetric Determination of Furfural by Spectrophotometry.*—Two methods involving measurement of the optical densities of coloured furfural complexes have been investigated. One involving the furfural-sulphonated *a*-naphthol complex gave sufficiently encouraging results to warrant further investigation. A similar method for the determination of uronic acids is being sought.

(iv) *Pentosan Contents of Some Eucalypts.*—Pentosan determinations on samples of jarrah, karri, and Western Australian blackbutt showed no appreciable difference between samples from pure and mixed forests, and also that the species fell into three definite groups, jarrah having the lowest pentosan content and karri the highest. These results confirm those obtained previously and show that in cases of doubt in identification the pentosan determination could be of assistance.

(*e*) *Eucalypt Kinos and Tannins.*—Several eucalypt kinos and commercial tanning agents have been examined by paper partition chromatography and shown to be heterogeneous. Two of the components of the kino of marri (*E. calophylla*) have been isolated and identified as aromadendrin (3,4',5,7-tetrahydroxyflavanone) and kaempferol. The examination of a third component is continuing.

(*f*) *Pulp and Paper Investigations.*—(i) *Variation of Pulp Properties within a Cross-section of Radiata Pine.*—At constant values for total alkali, sulphidity, and liquor ratio, wood from the first twelve annual rings has been converted to pulp of a specified permanganate number by varying the time of cooking as determined by pilot cooks on each ring. The pulps so obtained, and hence cooked to the same degree, are being evaluated for the purpose of correlating strength properties with fibre length, fibre diameter, and other physical characteristics which have been determined by the Section of Wood Structure.

(ii) *Permanganate Number.*—Two methods for the determination of permanganate number have been investigated over a wide range by application to four eucalypt kraft pulps and by varying the amounts of the reagents. With both methods there was a straight-line relationship between the amount of permanganate added and that consumed by the pulp, provided that the amount added exceeded a specified minimum quality.

(iii) *Influence of Electrolytes.*—The practical value of sodium hexametaphosphate has been demonstrated by its application in the development of beater curves. With both long-fibred sulphite pulp and eucalypt kraft strength properties for the unbeaten pulp were enhanced and beating was accelerated. The action of sodium hexametaphosphate as a dispersive agent has been illustrated by adding this reagent to the pulp after the latter had been beaten. Strength properties of the handsheets were greater than those of sheets made from the untreated beaten pulp.

(iv) *Beater Addition Agents.*—Of three addition agents of the wetting type which have been investigated "Lissapol", non-ionic, retarded the development of pulp strength properties, "Comprox", anionic, had little if any influence, but "Triton F", cationic, enhanced their development.

(v) *Lampen Mills.*—The comparison of the performance of various Lampen mills has been made on long-fibred and eucalypt pulps. In addition to the comparison between mills owned by the pulp and paper companies and by this Division, extensive work has been done in comparing mills wholly or partly made in Australia with those owned by this Division.

(vi) *Tear Testers.*—Four sectors which are now available with the Dynamic tear tester have been compared with handsheets of various basis weights in order to determine the working range of each sector, as well as to obtain data on their performances. A very light sector 16 times as sensitive as a standard sector and intended for use in fundamental studies on sheep properties has given highly satisfactory results. The design of a suitable pointer to be used in conjunction with this sector is still being investigated.

(vii) *M.I.T. Folding Endurance Testers.*—Experimental work on these testers has been continued with the object of limiting variance of mechanical origin. The cause of high first readings has not yet been revealed.

(viii) *Inspection and Testing of Manufactured Equipment.*—Twenty-four tearing resistance testers, manufactured by an Australian company, have been inspected and calibrated by the Division before delivery. The majority of these were for overseas consignees, mainly in the United Kingdom, but also in Sweden and the United States.

4. Timber Physics.

(*a*) *Physical Properties of Wood and Related Materials.*—The shrinkage and density of additional Australian and New Guinea species have been measured and a study of the standard methods of shrinkage determination continued. This study included comparisons of the observed volumetric shrinkage with that calculated from linear shrinkages, and of the shrinkage of specimens of standard size with that of small thin specimens. A study of the physical properties of wallboards has been continued with the object, *inter alia*, of standardizing testing methods. This work included water immersion tests at different temperatures, shrinkage tests, a study of capillarity, and the determination of the relationship between electrical resistance and moisture content.

Apparatus has been assembled for a study of the mechanism of sorption of water by wood. Preliminary tests have been made to study the variation in the shrinkage intersection point from early wood to late wood.

The thermal conductivity and specific heat of standard and tempered "Masonite" have been measured. The error due to the finite heat capacity of the thermocouples has been investigated. The use of electrical analogues for the investigation of certain errors in the equipment has been studied. A new apparatus using a different principle has been constructed for measuring thermal conductivity to obtain a check on the accuracy of the existing equipment.

Tests are in progress to determine the way in which the electrical resistances of typical species of timber vary with moisture content, temperature, and grain direction. Specimens from five trees each of myrtle beech, tallow wood, and hoop pine are being tested at moisture contents from 0 to 20 per cent. at temperatures from 20 to 80° C. Preliminary tests have been carried out on myrtle beech specimens to find the best method of resistance measurement.

The use of the electrical resistance moisture meter for measuring the moisture content of plywood sheets has been investigated. An experimental press was constructed to drive needle electrodes to predetermined depths in specially glued plywood specimens. Measurements were made with the needles closely approaching and also penetrating the glue line and a comparison made with the moisture content of the sheets as determined by oven drying.

An analysis of the results of tests to determine the dielectric properties of mountain ash revealed an unexpected relation between dielectric constant and frequency, and similar results were obtained using a different type of instrument.

(*b*) *Studies of Creep in Wood.*—Tests on initially green mountain ash beams are almost complete. Tests on initially green model beams which had been lacquer coated to reduce the rate of drying were unsatisfactory because the coating crazed and a number of beams twisted badly. This was overcome by the use of thin envelopes of "Alkathene". Tests on dry beams have been extended and failures have occurred between 30 per cent. and 45 per cent. of the short-time ultimate strength in periods of three weeks and upwards. The effect of temperature on creep in wooden beams is being studied by testing model beams under controlled conditions.

A group of dry mountain ash tension specimens at various stresses has been set up in an air-conditioned cabinet controlled at 75 per cent. relative humidity and 35° C. A similar group of green tension specimens has been set up under saturated conditions. Increases in strain of 10 to 70 per cent. have occurred in three months in these groups.

Shear tests have been carried out on dry mountain ash specimens at stresses ranging from 50 to 85 per cent. of the short-time ultimate strength to determine the ultimate shear strength under prolonged loading. Some specimens at each stress failed after fifteen minutes to one month under load.

A study of the effect on accuracy of the thickness and spacing of cross-hairs in creep instruments and the design and dimensions of reference marks on the targets has been completed. The results obtained are applicable to measuring microscopes in general.

(*c*) *Battery Separators.*—Electrical and mechanical tests have been carried out on Vanikoro kauri, jelutong, and plantation-grown radiata pine. The results for jelutong and radiata pine were good enough to justify life tests, which are now nearly complete. It seems

probable that radiata pine will be satisfactory and in a few years' time when mature trees are available may ease the acute shortage of suitable timbers.

Electrical and mechanical tests have been made on separators of North Queensland kauri, *Agathis palmerstoni* and *A. microstachya*, to see if there is any significant difference between the two species. Although the manganese content of untreated *A. microstachya* was only about 30 per cent. of that of *A. palmerstoni*. its mechanical properties were considerably inferior.

(*d*) *Ultrasonics.*—Further studies have been made of the effect of ultrasonics on wood fibres. As a result of these experiments, an air-backed crystal-holder and an oil-cooling system have been devised to allow the equipment to be operated satisfactorily for periods up to two hours. A study is being made of methods of intensity measurement, as it has been found necessary to determine the effect of varying intensities on the degradation of wood fibres.

(*e*) *Electrical Resistance Strain Gauges.*—The study of the physical properties of electrical resistance strain gauges has been continued. In particular, resistance variation immediately after bonding has been investigated.

A preliminary study was made of the properties of strain gauge wire in connexion with unbonded strain gauges. It was found that the three wires used (American and English "Advance" and English "Eureka") possessed quite different characteristics.

The development of plastic-backed gauges made without end loops (after Gaustafssen) has been continued. The construction of a jig has simplified manufacture to such an extent that it can now be considered a routine operation. Although all aspects of the behaviour of these gauges are not yet understood, some are included in nearly all tests undertaken to obtain further information.

The use of resistance strain gauges on green timber has been attempted. The gauges are attached to a fine metal foil, itself attached to the specimen. A study of the effects of the foil is still proceeding. The search for a suitable locally available waterproofing agent has continued. Tests are being carried out to determine the effect of gauge length on the apparent strain readings obtained when using these gauges on timber.

5. Timber Mechanics.

(*a*) *Species Testing.*—A large number of mechanical tests has been carried out on specimens from about 150 trees in order to determine average values of their properties. The species principally represented were jarrah, radiata pine (from Victoria), mountain ash, and hoop pine; a few logs from many other species—messmate stringybark, mountain grey gum, tallow wood, spotted gum, rose gum, brush box, scribbly gum, turpentine, white stringybark, and red mahogany—were also handled. As well as the Australian-grown material, species from New Guinea (rosewood and terminalia), Borneo (ramin), and Fiji and the Solomons were tested; many of them are, or are likely to become, of importance on the Australian market.

The reduction in the number of trees from which logs were obtained is a reflection of prevailing labour and transport conditions, which are making it increasingly difficult to obtain adequate material for species testing. This has been aggravated by the change in the sampling procedure of the laboratory, which now requires more logs for fewer test specimens.

(*b*) *Studies of Properties and Testing Methods.*—With the objective of international standardization, three test methods are being investigated in the laboratory. The study of the compression-perpendicular-to-grain test, which is performed differently in Great Britain and North America, has been continued and extended. Correspondence with the United States Forest Products Laboratory concerning the shear test, for which the British and American standards also differ, has resulted in an agreed plan for studying the test; material has been prepared in America and despatched to Australia for testing here, while matched material is held for testing there. The single-blow impact test is also carried out to different standards, quite different machines being used; at the request of the Timber Mechanics Corresponding Committee of the British Commonwealth Forestry Conference many of our data on the two tests have been collated to be sent to Canada, whence it is proposed to circulate all available information throughout the British Commonwealth and to the United States.

In studies of fundamental properties one investigation made concerns the value of the apparent modulus of elasticity in relation to the size of the compression specimen; this is important, as a small specimen is frequently used when insufficient material is available for the standard size or to obtain close matching in an investigation of effects. The effect of moisture content on the tensile strength of mountain ash has been investigated, as information available on this general relationship was slight, and it was required for an inquiry into fibre strengths. Arising from discussions at the Timber Mechanics Conference in 1948, a study of shrinkage intersection points and moisture corrections for strength was undertaken, and work on it has progressed steadily. The relationship between resilience and toughness values for a number of species has come under review. Density and the impact hardness index obtained from a ball-drop test are related, as has been shown, with a very high correlation between species values.

(*c*) *Silvicultural Tests.*—Work on the project has been concentrated on the development of the micro-test technique, not only for the determination of tensile strength but also, lately, for the determination of density of the specimens in an attempt to use it as a measure of mechanical properties. About 10,000 tension micro-specimens have been tested during the year. From the patterns of strength variation which have been obtained there is now little doubt that the method can be used to investigate the effect of silvicultural procedures on mechanical properties. The work on density, however, has not yet proceeded far enough for the potentiality of the method to be assessed.

(*d*) *Housing and Construction.*—Attention has been given to several aspects of the use of timber in housing and construction, the work being directed toward greater economy in the use of the material.

(i) *Survey of Housing Practice.*—The survey of the current use of structural timber in houses was extended to New South Wales, Victoria, and Queensland. Subsequently a revision of the pamphlet on building frame sizes and spacings was undertaken, and considerable progress has been made with it.

(ii) *Timber Connectors.*—There has been no great change in the long-time loading project; a few specimens have failed but the majority continue to carry their loads. As a result of observation of the specimens, the use of a stitch bolt through the end of a tension joint will probably improve its performance and an experiment is proposed to test the suggestion. Assistance has been given in developing a pressed shear plate similar to that used in the United States. At the present time plates are cast and it is difficult to obtain supplies.

(iii) *Columns.*—Work has proceeded on the short-term loading aspects of this investigation, green mountain ash being under test. When this species is tested, a start will be made with setting up tests under long continued loads. An experiment was carried out

to determine the effect of orientation of growth rings with respect to the chosen direction of buckling; the non-significance of the results will simplify selection of material for further tests.

(iv) *Fibre Building Boards.*—Testing has continued of 26 different brands of imported boards. As it is desirable to spread the sampling as widely as possible, it has not yet been completed for the majority of the boards; in a few cases it may be necessary to terminate the tests without obtaining the desired coverage. Investigations of the strength of chip binder board and some other tests of factors affecting the strength of fibre boards have also been conducted.

(v) *Built-up Structures.*—In the design of timber structures it is usually assumed that the distribution of stress is not greatly affected by the joints, the error involved being covered by a factor of safety. In many cases, however, it is likely that secondary stresses arising at joints will be large compared with the primary stresses, so that a more precise knowledge of their magnitude may lead to design economies. An investigation of such stresses has been initiated, the simplest types of joints being used in the first stages.

(vi) *Flooring.*—The strength and stiffness of floor boards have been investigated previously in this laboratory, and the work has now been extended to cover the combined action of flooring boards and joists. At first stiffness only will be investigated.

(*e*) *Growth Stresses in Trees.*—Work on the main project has been limited to the measurement of the release of longitudinal strains in one or two logs, but arising from it, it has been suggested that if the material in the growing tree "creeps" under its self-imposed stresses, there may be "creep recovery" when the tree is felled. This recovery would, of course, be distinct from immediate elastic recovery. It has been difficult to investigate such possible creep recovery, but indications are that the phenomenon does occur towards the pith and that the rate of recovery decreases with time.

Other experiments are being conducted in an attempt to produce "brittle heart" material in the laboratory and, at the same time, to test the significance of age and rate of growth of the material on its production. If successful, these tests will indicate the effect of conditions on the formation of the material in the living tree.

6. Timber Seasoning.

(*a*) *Veneer Drying.*—Aerodynamic studies show that air circulation conditions satisfactory in units designed for "tray" drying are not suitable for vertical "finger" racking. Laboratory tests of the value of diffuser screens in the air path adjacent to the stack sides were commenced. Results have indicated that this equipment can provide an inexpensive but effective method for ensuring satisfactory air circulation with vertical racking and a system to incorporate some of the flexibility and low labour costs of vertical racking with suitable restraint was designed. Evidence was obtained that conditions for drying refractory veneer can be further improved by ensuring swirl in the air flow to minimize the effect of a boundary layer condition which develops at the surface of veneers during drying. Work on this aspect is continuing.

(*b*) *Vapour Drying.*—Studies which have been continued have fallen naturally into three divisions: (i) the seasoning of pervious timbers in board and joinery sizes, (ii) the seasoning of impervious timbers of similar dimensions, and (iii) the partial drying of large sections of non-durable species requiring preservative treatment. On the seasoning side, aspects examined have been the effect of working fluid, working pressure, wood temperature, and distillation rate on drying time and quality. The work has shown that, under laboratory conditions and with suitable process control, 1-in. thick "ash" eucalypt stock can be dried from the green condition and free from degrade in only five days, whereas this material normally requires ten to fourteen days in an orthodox kiln. Further, the seasoning of pervious timbers can be accomplished effectively in about 5 to 10 per cent. of the time required in an orthodox kiln. On the preservation side, the relation of moisture content and drying time with preservative penetration and absorption was examined. It was shown that four to five hours' vapour drying was effective in drying radiata pine railway sleeper sections from the green condition to a moisture content which gives satisfactory creosote penetration and absorption during subsequent pressure preservation treatment. The laboratory studies have demonstrated that the four Australian timbers studied can be vapour-dried, but they have also shown that a number of aspects of plant engineering, control, and operation need further development.

(*c*) *Kiln Drying.*—At the request of the Tasmanian Hydro-Electric Commission, kiln-drying schedules were established for 2-in. thick Tasmanian messmate stringybark required for low-pressure pipe lines. Kiln schedules for ramin were developed at the request of the Sydney and Suburban Timber Merchants Association and the Sarawak Forest Department.

(*d*) *Kiln Design and Plant Layout.*—Some 240 drawings covering drier designs for solid timber, core board, and veneers were prepared, on request, for 27 wood-processing organizations. Seasoning plant layout plans, to ensure integration of seasoning equipment and handling methods with existing facilities or future plant development, were also prepared for thirteen firms. Visits were made to 42 commercial plants in all States to advise on seasoning practice and drier performance. Recommendations with respect to modifications of equipment or production methods were made where warranted. Drawings for sawdust and mill waste burners, designed to suit the varying loads and operating conditions involved, were prepared for some 80 sawmillers and joinery manufacturers. Inquiries were also received from England, New Zealand, South Africa, Pakistan, Mauritius, Chile, and Israel. A study of the effect of plant drying capacity on kiln drying and plant installation costs in Australia was made. It was shown that the unit costs of kiln drying for a particular kiln size are reduced by some 30 per cent. by increasing plant capacity from one to two kilns and to less than half by increase to four kilns. Examination of the relative economy of continuous and intermittent kiln drying at small plants was commenced. For continuous drying, air circulation and heat were provided for 24 hours each day; for intermittent drying air circulation was supplied for 24 hours but heat for only eight. For 1-in. thick stock, under summer conditions, the time required in kilns appeared to be in the ratio of 4:7 (continuous: intermittent).

(*e*) *Railway Sleeper Investigation.*—Studies of the causes of physical and mechanical failure in railway sleepers under service conditions and of methods of increasing the track life were continued. An examination of the lateral shear resistance of two types of rail fastening widely used in Australia was completed under laboratory conditions. This included a study of the influence of shear plates on the load-bearing capacity of rail spikes. The use of shear plates considerably reduced the stress concentration, enabling the combination to support for the same deflection considerably larger loads than the spike alone. A survey of temperature and moisture content changes in sleepers in service was commenced: specially prepared electrodes were inserted to varying depths in

a number of sets of sleepers over a range of sites. Apart from the intrinsic value of these data, they will enable field conditions to be simulated within the laboratory, particularly with respect to surface weathering and spike hole deterioration.

(*f*) *Building Materials and Products from Waste Wood.*—Laboratory studies of the effect of species, particle size, moisture content, resin type and content, and pressing pressure, temperature, and time in relation to the manufacture of hardboards from the sawdust of Australian timbers were completed. Similar studies of the value of other waste materials, including shavings and chipped and milled veneer waste for low-density coreboard manufacture, were commenced. An estimate of the economics of manufacture of these products in Australia was prepared, a steady demand for information on their production having developed.

Work on the development of paper roll plugs from sawdust-synthetic resin combinations was carried out. Initial problems of production included moisture content, temperature, and compression gradient effects, and a determination of suitable resin and density values to avoid risk of possible damage to certain processing equipment. Commercial production has been undertaken. Tests on a number of overseas waste wood binder boards were carried out.

The effects of resin content, temperature, and pressure on the properties of bagasse-resin combinations for hardboard manufacture were studied.

(*g*) *Other Investigations.*—A limited examination of equilibrium moisture content temperature relationships for wood in super-heated steam at atmospheric pressure was carried out to facilitate an understanding of certain aspects of vapour drying. Graphs plotted for values of both mountain ash and hoop pine, obtained experimentally for temperatures up to 310° F., demonstrated a curve-form similar in nature to the equilibrium moisture content/wet bulb depression relationship for temperatures below 212° F.

Experimental studies on the drying of wood in liquids immiscible with water, under reduced pressures, were commenced. Using invert sugar as the treating medium, anti-shrink techniques were developed to prevent the typical radial cracking of "green" disks cut from tree stems required for record purposes. The influence of method of stacking, stack size, and material thickness on temperature/time relationships at the core of solid and semi-solid piled stacks of European softwoods, steam-heated as a sterilizing treatment for wood wasp infestation, was examined at the request of the Commonwealth quarantine officers and State forestry authorities.

Co-operative studies of the relative economy of milling, seasoning, handling, and laying flooring $\frac{5}{16}$-in. thick and $\frac{3}{4}$-in. thick were commenced.

The correspondence courses on kiln operation were continued: 27 students enrolled and eleven completed the courses during the year.

7. Timber Preservation.

During the year there has been a marked increase in activity in the wood preservation field in Australia, as under present economic conditions treatment of timber for external service is becoming increasingly desirable. There is now every indication that a wood preservation industry will develop in the next few years, and this has been reflected in the volume of requests for technical advice received from Government departments, industry, and the public on problems of general wood preservation and insect damage. Some inquiries have involved a considerable amount of work, one requiring a visit to New Guinea.

(*a*) *Field Tests.*—Pole and fence post tests in New South Wales, in which the effectiveness of various wood preservatives is being compared in different sites, were inspected during the year. Similar tests in Victoria and South Australia are due for inspection in the coming year. Attention has been given to selection of new sites with high decay or termite hazard in Victoria and Queensland for future tests.

(*b*) *The Preservative Treatment of Eucalypt Heartwood.*—Australia has long been known as a sleeper-exporting country and its durable timbers have enjoyed a wide reputation. However, during the past year two of the State railway systems have been seeking supplies of sleepers from overseas to meet local deficiencies. Ordinary preservative treatments are not effective with sawn eucalypts in a form such as sleepers because of the difficulty of penetrating eucalypt heartwood. During the year a pilot plant was completed to treat such material at pressures up to 1,000 lb./sq. in., following experiments which showed that under these conditions adequate absorption was obtained through end penetration. The plant will be used mainly for the treatment of rail sleepers and crossarms for transmission poles. It is hoped that successful demonstration of this treatment will ultimately result in the wide-spread use of preservative-treated eucalypt sleepers in Australia. Co-operative tests with the Victorian and Western Australian Railways and the Postmaster-General's Department are planned for the coming year.

(*c*) *Permeability Studies.*—This new project involves a fundamental study of the problems of liquid and vapour penetration in wood. It has the practical object of explaining differences in the penetrability of wood to preservatives and possibly, as a result, of improving existing methods of treatment. It is a long-term project which will be interrupted during the coming year when the officer mainly responsible will be abroad undertaking training studies in this field of research.

(*d*) *Metallic Naphthenate Preservatives.*—The investigation to study the permanence of metallic naphthenate preservatives and their toxicity to wood-destroying fungi is now almost complete and has yielded results which will be of value in establishing a satisfactory specification for this type of preservative. With the test fungus used it has been shown that the toxicity of naphthenic acids increases with the acid number. Further increase in toxicity by addition of copper to the molecule is most marked at low acid numbers, but is negligible when the acid number exceeds 250. Permanence tests involving leaching and weathering are in progress.

(*e*) *The Preservative Treatment of Crossarms.*—The survey to determine the causes of failure of crossarms has been completed for three States—Western Australia, Victoria, and New South Wales—and has involved the inspection of several thousand arms which have failed in service for various reasons. The results indicate strongly the economic benefit which should be obtained by pressure treatment with oil-type preservatives, and co-operative tests with pole-using authorities have been arranged to demonstrate the necessary treatment process.

(*f*) *The Toxicity and Permanence of Water-borne Preservatives.*—In this new investigation developed during the current year, a laboratory study of the toxicity and permanence of water-borne preservatives is being made. The testing procedure involves determination of toxicity by the agar tube method, using three selected wood-destroying fungi, determination of rate of leaching under standard conditions by analysis of leach waters, and finally, assessment of

protective efficiency by accelerated laboratory decay tests of treated wood blocks. Although this type of test is not intended to supplant field tests, it will provide a method for screening preservatives and also for judging their suitability for special conditions of service as, for example, in the treatment of mining timbers. Work during the year has been mainly on toxicity testing and on the development of analytical methods preparatory to leaching studies.

(*g*) *Timber Mycology.*—The investigation to determine the comparative resistance to decay of various timbers in accelerated laboratory tests is continuing. Development of testing technique has been almost completed and it has been shown that the soil-jar method is capable of giving rapid results even with durable timbers. Selection of suitable test fungi is still in progress and with the more important species, such as *Trametes lilacinogilva* and *Coniophora cerebella*, tests of different strains are being made.

Collection of representative specimens to establish the relative durability of a large number of Australian timbers is now well advanced.

During the year many new cultures of Australian and New Guinea wood-destroying fungi have been made and approximately 500 cultures are now maintained in the standard collection. Collection of herbarium material has continued and considerable time has been spent in the identification of fruiting bodies collected. Work on identification from cultural characteristics is progressing and methods of producing fructifications of wood-destroying fungi in the laboratory are being examined. A series of notes on Australian wood-destroying fungi is being prepared, giving geographic range, host species, type of rot, and cultural characteristics of the causal fungus.

(*h*) *Other Investigations.*—Following successful laboratory tests in which DDT and BHC added to the glue in plywood prevented *Lyctus* borer attack, large-scale tests are now in progress in co-operation with the Veneer and Gluing Section. To determine the termiticidal properties of dieldrin, samples have been treated and forwarded to the Division of Entomology in Canberra for testing. Collection of *Anobium*-infested timber is continuing with the object of breeding a sufficient number of beetles to undertake tests of the susceptibility of radiata pine to this borer.

8. Veneer and Gluing.

(*a*) *Veneer and Plywood Manufacture.*—(i) *Veneer Cutting.*—Veneers were cut from logs of twelve species from Australian sources and one from a plantation in Fiji. Most attention was give to some of the harder heavy eucalypts, blackbutt, rose gum, and spotted gum, and to plantation-grown conifers. The importance of these investigations can be gauged from the fact that pre-war Australia produced almost 100 per cent. of her plywood requirements, but in 1950, about 15 per cent. was imported. In addition, about 25 per cent. of the logs for the Australian output was imported and the demand continues to rise with the increased rate of building. Investigations relating silvicultural treatment to potential yield of veneer have been continued in collaboration with State Forestry Departments. They involve tests of thinnings from plantations of hoop, radiata, slash, and loblolly pines and determination of the optimum diameter at which trees should be pruned to provide high-grade veneer logs at commercial maturity.

(ii) *Plywood Manufacture.*—Plywood has been made from all species peeled and observations have been made on the quality in relation to current Australian practices. The plywood from the hard, heavy eucalypts was mechanically good but difficulties will be experienced in producing from these species plywood which is acceptable for the major Australian use, furniture. On the other hand, such plywood would be very suitable for manufacture of boxes, cases, and other packages in which appearance is of secondary importance to mechanical strength.

(iii) *Immunization of Plywood against Lyctus Attack.*—Following successful laboratory tests of *Lyctus*-susceptible veneers made into plywood with glues containing BHC or DDT, the co-operation of the Australian Plywood Board and the Queensland Forestry Department was obtained in the production of further material on a commercial basis and plywood has been installed for service tests in the Division. Only a few months after manufacture untreated sheets of plywood were badly attacked by *Lyctus* but no damage has occurred in casein-glued plywood incorporating BHC at the rate of slightly less than 1 lb. per 1,000 square feet of single glue-line, costing about 6d. per 100 square feet of plywood. Observations will be made over a number of years.

(*b*) *Gluing Research.*—(i) *Protein Studies.*—Investigations on proteins have been carried out mainly with the ultimate object of elucidating the principles underlying the formation and structure of protein gels. Particular attention has been paid to the milk protein, casein, and by arrangement with the Dairy Research Section some problems of technological importance in the dairy industry, especially the thickening of evaporated milk in storage, have been considered in addition to problems connected with adhesion. On the fundamental side, two specific problems have been investigated: the mechanism of gelation in casein-alkali systems and the mechanism of milk clotting by enzymes.

The changes in the casein molecule upon alkali treatment have been studied by various methods. Molecular symmetry as deduced from intrinsic viscosity measurements is sufficiently constant with time to indicate that intramolecular unfolding of polypeptide chains is not an important factor in gelation. Other aspects of the problem investigated include the possible implication of arginine in the gelation process, the effect of neutral salts on the viscosity of casein dispersions, the swelling and stability of casein gels, the rheology of dispersions of a relatively soluble casein fraction in sodium hydroxide solution over a pH range lower than that previously investigated for whole casein, and the rheology of alkaline rennet casein dispersions.

The action of rennet on milk is of major industrial importance in the production of casein for glues and plastics and in the manufacture of cheese. Experiments have been carried out using reconstituted casein solutions which are virtually calcium-free and therefore unable to coagulate even in the presence of the enzyme. However, precipitation can be effected in the usual way by the addition of acid, and comparisons have been between paracasein from solutions which have been treated with rennet and casein from untreated solutions, and between the filtrates from these solutions. Striking differences in solubility between casein and paracasein have been observed, particularly in regard to behaviour in the presence of neutral salts. The average paracasein molecule is slightly more symmetrical in shape than casein and the extinction coefficient in the ultraviolet region is slightly larger, although the absorption spectra are of similar shape. When the proteins are coupled with diazonium salts significant differences, which may be associated with an increase in the reactivity of the histidine upon treating casein with rennet, are observed in the two absorption spectra in the visible region. This hypothesis, which can help to explain the difference between the behaviour of casein and paracasein, is supported by titration data. Electrometric titration of acid groups and formal titration of lysine amino groups show only small differences

between the two preparations. Titration in alcohol to the thymolphthalein end-point shows a considerable increase in basic groups minus arginine upon rennet treatment, and an increase is also shown in carboxyl groups as measured by titration in acetone solution to the naphthyl red end-point. With regard to the filtrates, various tests and fractionations have been carried out, and ultraviolet absorption and gravimetric methods have been used for estimating quantitatively the nitrogenous constituents. The presence of a proteose or peptone in the filtrates resulting from precipitation of the rennet-treated solutions has been definitely confirmed. Parallel with the investigation of the enzyme action on the casein, the effect of heat has been examined, as it has been noted that casein solutions heated above 65° C. display sensitivity to calcium ions similar to that of rennet-treated solutions. However, there are indications that the increase in sensitivity is due to a mechanism distinct from that brought about by the enzyme. The possibility of the rennet reaction involving reduction of the disulphide linkage of cystine was examined, but tests showed that free sulphydryl groups were absent in all solutions.

The reaction between histidine and diazonium salts is being investigated by a spectrophotometric method, with interesting results which may lead to a method of simultaneously determining histidine and tyrosine in the intact protein.

(ii) *Applied.*—General observations have been made on the gluing qualities of more than 20 species. Special investigations were carried out to determine the reduction in glue strength of veneers impregnated with boric acid or borax and of spotted gum when gluing is delayed for periods up to six months after planing. Further assistance was given to the Division of Industrial Chemistry in the development of tannin formaldehyde adhesives for semi-commercial trials.

(*c*) *Technical Assistance.*—Requests for assistance were received from the veneer, plywood, glue, and furniture manufacturing industries, from Government departments, and from other users of timber and glues. These covered a wide range of problems including the design and lay-out of veneer and plywood plants, manufacturing techniques, gluing of metals to wood, various laminated constructions for sporting equipment, and the development of Australian standards for plywood and glues.

9. Timber Utilization.

(*a*) *Timber Uses.*—Requests for information and assistance with problems connected with timber utilization were received in increasing number during the year from the timber industry, private individuals, and governmental and semi-governmental organizations. Information was supplied on the suitability of various timbers for the following uses:—agricultural machinery, archery, bakers' peels, bearings, boat building, body building, bridge decking, building boards, butchers' blocks, cabinets, carpenters' rules, castanets, contact breaker arms, cooperage, clothes pegs, cooling towers, croquet mallets, dry cleaning equipment, egg boxes, fence posts, filter presses, floor blocks, flush doors, footwear, golf club heads, handles, harpsichords, heat former blocks, house construction, ice cream spoons, insulator spindles, knife handles, laboratory benches, ladders, loading ramps, mallets, matches, meteorological instrument cabinets, motor bodies, naval targets, oars, ovens, palings, piling, rifle furniture, rumblers, shingles, shipbuilding, ships' masts, shoe heels, shoe lasts, skis, slide rules, sporting goods, tent pegs, transformer components, turnery, vacuum filters, vat construction, wooden machinery components, wood wool, wringer bearings.

(*b*) *Manufacturing Processes.*—Sawmill layouts and notes on characteristics of equipment were prepared for operators desiring to improve existing or to establish new sawmills. Questions stimulated by data previously released on log edgers, rip benches, gauges, and other efficient devices were dealt with. Assistance was given to firms in re-organizing timber handling practices. A mill study to determine the quantitative and qualitative yields obtainable from head logs of alpine ash was completed. Advice was given regarding the finishing of flooring, removal of stains from weatherboards, bleaching of timber, and photographic veneering.

(*c*) *Waste Utilization.*—Investigations were continued on the factors influencing the properties of hot pressed pulp boards. At 180° C. and 350 lb./sq. in. pressure, no effective bonding occurred in pulps reduced below 26 per cent. moisture content, but bond improved as moisture increased up to about 50 per cent. Water burn became troublesome at high moisture content and staining tended to occur more readily as pressure increased. Sawdust blood mixtures in various proportions have been pressed under a range of temperatures and pressures, attractive products resulting within the limits 125-150° C. at 200 lb./sq. in. Economic factors affecting commercial production were examined in relation to several manufacturing proposals.

Experiments were carried out on the production of board from seaweed submitted by the Division of Fisheries (*see* Chapter XI., Section 9 (*b*)) and cane fibre submitted by a sugar milling company.

Information on the fuel value of sawdust and on its burning under water-tube boilers, in incinerators, and in producer-gas generators was distributed and inquiries dealt with regarding the briquetting of sawdust.

(*d*) *Sawing Studies.*—Experimental cutting with circular saws was continued and energy consumptions were compared at various feed rates for saws with teeth shaped and spaced differently. Field and laboratory studies on chain saws were continued. Assistance was given on developing a powered grinder for the sharpening of sawing chains in lieu of hand filing, and descriptions were released in the *News Letter*. Demonstrations and training were given to forest workers on the preparation and operation of chain saws.

(*e*) *Standards.*—Collaboration with the Standards Association of Australia was continued on all matters pertaining to timber standards. Executive duties were performed for the Timber Industry Committee, technical liaison work was continued with the sectional committees, and an active part was taken in preparing and reviewing drafts of several proposed standards. Grading rules for hardwoods of south-east Australia and for radiata pine were advanced through several committee stages. Profiles for pine flooring were considered in two States. A proof issue of a standard for fibre-board butter boxes was circulated for public critical review. Specifications for fresh fruit cases were drafted and reviewed. A standard for waterproof plywood in marine and standard grades was endorsed for publication. A draft standard for wooden windows was submitted to the printers for preparation of a proof issue. Drafts of standards on kitchen fitments, wooden doors, and wooden door frames were lodged for preparation of papers for postal ballot. Notes on single-story timber buildings were forwarded to collaborators for consideration while drafting a code of practice. Progress was made on the preparation of standard definitions of terms used in forest products research in Australia.

XIV. BUILDING.

1. General.

Research on the properties and uses of building materials has been continued in the Division of Building Research at Highett, Victoria. This work is complementary to work on design, construction, and performance of buildings carried on by the Commonwealth Experimental Building Station of the

Department of Works and Housing at Ryde, New South Wales. Research on timber as a building material is undertaken by the Division of Forest Products and is reported in Chapter XIII. Studies of the properties of soils in relation to building foundations, carried out by the Division of Soils, are reported in Chapter II., Section 4, and work on cement and ceramics by the Division of Industrial Chemistry in Chapter XVII., Section 3.

Division of Building Research.—The work of the Division is described in the remainder of this Chapter.

Progress during the year has been satisfactory in most of the research projects undertaken by the Division but in some it has been disappointing, mainly because of the difficulty of obtaining research staff.

The only new project was the preparation of a paper on the weathering and durability of building materials in the tropics at the request of the organizers of the International Building Research Congress to be held in London in September, 1951 as part of the Festival of Britain. This entailed an intensive review of the voluminous literature on weathering and durability in general and a visit to northern Australia to study conditions at first hand.

Close and cordial contact has been maintained with industry, the Standards Association of Australia, and Commonwealth and State Departments interested in building and development. Some 2,500 inquiries (an increase of nearly 40 per cent. compared with last year) have been answered.

The Division contributed several exhibits to the Building Research Display organized by the Building Research Liaison Service of the Commonwealth Department of Works and Housing, which was shown during the year in all State capital cities except Brisbane.

Officers of the Division delivered courses of lectures to students of the University of Melbourne, the Melbourne Technical College, and the Sydney Technical College.

2. Concrete Investigations.

(*a*) *Foamed Concrete.*—Work on the preparation, properties, and uses of foamed concrete was begun some years ago because it was apparent that the scarcity of detailed information on the manufacture and properties of this technically promising material was retarding its large-scale production in Australia. Although much remains to be done, the work already accomplished has been in no small measure responsible for the rapid increase in the production of foamed concrete which is now taking place in this country.

During the past year quantitative information was obtained on the relationships between method of foaming, grading of sand, density, mechanical properties, rate of drying, dimensional changes, and water absorption.

The properties of foamed concrete made in a commercial plant were compared with those of material made by the same method in the laboratory; on the whole the factory-made material was better.

The pozzolanic activity of fly ash and diatomite was investigated and it was found that these materials are suitable for use as pozzolans in foamed concrete providing that they are pulverized so that at least 85 per cent. passes a 300 B.S. sieve. Pozzolanic activity of fly ash was found to be increased by calcination at 1,500° F.

(*b*) *Theory of Rupture of Concrete.*—The purpose of this investigation is to determine the criteria for failure of concrete under load. This information is of basic importance in the rational design of all concrete structures. The study requires a comparison of the ultimate strength of material subjected to uniaxial and to biaxial tension. Much attention has been paid to devising a suitable testing technique for determining the strength under biaxial loads, so far without success, but promising results have been obtained with a form of uniaxial tension test. An ordinary cylindrical specimen lying on its side is loaded in compression, so that in effect the test piece is a thick disk subjected to concentrated loads at opposite ends of the diameter. Failure occurs in tension along this diameter. A photoelastic analysis made by the Melbourne Technical College at the request of the Division showed that the tensile stress distribution across the diameter is not quite uniform, but the tests made so far suggest that values obtained are closer to the true tensile strength of the material than those given by other methods.

(*c*) *Durability of Concrete.*—Inquiries made during the year failed to reveal any durability problems peculiar to Australia, and since those troubles that have been reported are receiving wide attention overseas the study of durability will not be a major project. However, attention has been given, and will continue to be given, to specific instances of failure of concrete. For example, a short investigation has been made of the deterioration of cement mortar renderings on gypsum plaster walls of houses in the Murray Valley (*see* Section 3 below).

Because of some doubt about the reproducibility of the Mielenz Test, proposed in the United States of America for determining whether an aggregate is likely to be dangerously reactive with portland cement, a small programme of tests is being carried out in association with the Department of Works and Housing. Samples of aggregates have been tested by both bodies and the results so far have shown agreement.

(*d*) *Other Investigations.*—A series of tests to determine the effect on the ultimate compressive strength of hardened cement paste of the atmospheric temperature and humidity during mixing and setting has been completed and the results are being analysed to provide data on which to plan subsequent work.

Arising from the work of the Concrete Structures Committee of the Standards Association of Australia, a short investigation has been made to determine whether standard concrete test specimens should be cured in ordinary water renewed every 28 days or in water saturated with lime as recommended by the American Society of Testing Materials and the Laboratoires du Bâtiment et des Travaux Publics in France. The results, which are at present being analysed statistically, seem to indicate that the two methods of curing give similar results.

Advice on the manufacture of concrete roofing tiles was given to existing and potential manufacturers but no further work was possible on the mortar surface finish developed previously.

3. Gypsum Plaster and Plaster Products.

(*a*) *Developmental Work.*—(i) *Vermiculite Plaster.*—Plaster containing expanded vermiculite as an aggregate has been extensively used in other countries, especially the United States, for fire-retardant partitions and as a lightweight fire-resistant coating for structural steel work. Experiments with Australian plaster and vermiculite showed that suitably designed mixes are easily handled by normal plastering techniques, but serious trouble was encountered from efflorescence due to soluble salts formed by the slow decomposition of the vermiculite by the gauging water. As no reports have been received of similar difficulty in other countries, supplies of American and South African vermiculite are being obtained to see if the efflorescence is due to faulty technique.

(ii) *Load-bearing Plaster Slab Walls.*—Load-bearing plaster slab walls, similar to the well-known precast concrete walls, are being widely used in the lower

Murray Valley and are of considerable interest because the hourly stripping made possible by the rapid setting of plaster keeps capital costs to a minimum.

A survey revealed that despite the low rainfall external plaster walls are not successful because of the difficulty of protecting the plaster from the weather. As internal load-bearing partitions these walls show promise but more work is required on the design of the reinforcement.

(*b*) *Basic Research.*—(i) *Particle Size Distribution.*—The trouble, mentioned in the Second Annual Report (Chapter XIV., Section 5 (*a*)), that is caused by the finer fractions adhering to the walls of the gas elutriator has not been entirely overcome by the use of the available radioactive materials. Some plasters give more trouble than others but the reason for this is not known. It does not seem to be correlated with the degree of burning of the gypsum. Experiments in progress in which the finest material is removed by a special preliminary treatment and the rest of the sample is then submitted to fractionation are giving encouraging results.

(ii) *Mechanism of Setting.*—This work has been directed chiefly to microscopic studies of the crystal growth that takes place when the plaster is mixed with water. Contrary to expectations, the finest particles obtained by gas elutriation of a commercial plaster were the slowest to crystallize, and crystallized in a different form from those formed by the coarser particles.

Preliminary measurements have been made of the rate of heat development during setting.

(*c*) *The Decoration of Fibrous Plaster.*—Investigations into problems of fibrous plaster decoration are at present related to mould growth (chiefly on water paint films) and a greyish-purple stain caused by sulphide gases. These defects have caused trouble in pre-cast concrete and other houses and field experiments have been begun in co-operation with the Victorian Housing Commission to compare the mould resistance of a variety of commercial water paints. To correlate field behaviour with laboratory performance the rates of growth of moulds in humid atmospheres have been studied and analyses and estimations of the fungicidal ingredients of the paints made.

To indicate the presence of sulphide gases in dwellings, silver-plated brass strips have been substituted for the less sensitive lead acetate test papers formerly used. The tarnish formed on the silver can be used to assess the sulphide pollution.

4. Lime and Lime Products.

(*a*) *Survey of Australian Lime Resources and Industrial Plants.*—The lime industries in Tasmania and Western Australia have been completely surveyed and more works in Queensland visited.

(*b*) *Technical Advice.*—During the year the Division was asked by the Australian Aluminium Production Committee to co-operate in the consideration and designing of the lime-burning plant, an integral unit required in its production cycle. Recommendations for the type and design of kiln and the hydrating plant were made.

At the request of the Tasmanian Department of Industrial Development a report is being prepared on the industry in that State and recommendations will be made concerning its development.

Contact has been made with lime manufacturers and advice on plant and equipment and various phases of the production cycle has been given.

(*c*) *Lime Research.*—(i) *Limestone.*—The Permian limestones of Tasmania are being studied in detail, with special emphasis on the metamorphosed varieties from Mount Nelson, Sorell, and Sanford. A secondary investigation concerns the exact elucidation of the crystalline structure of the mineral laumontite and its dehydrated modifications.

(ii) *Lime and its Hydrates.*—The hydration products of lime are being studied. Samples of limestone, and lime produced therefrom, are being analysed preparatory to choosing a material for a standard sample.

(iii) *Role of Carbonation in the Hardening of Lime Mortars.*—Investigations are proceeding to determine if and to what extent carbonation is responsible for the hardening of lime mortars. The results so far obtained suggest that in addition to the chemical process of carbonation, mineralogical and structural changes occur in the mortar body. This secondary hardening can be due to a change from the amorphous form of calcium carbonate formed in the early stages of reaction to a crystalline form, to an inversion to calcite of an initially formed aragonite, or to a combination of both processes. It is not easy to determine the crystalline form owing to the extreme thinness of the carbonate films, and methods for these determinations are being considered.

(iv) *Correction of Unsoundness in Magnesian Limes.*—Recent cases of spalling in wall renderings have been traced to unsoundness in the lime, which had a comparatively high magnesium oxide content and was hydrated at atmospheric pressure. When such lime is exposed in a rendering for a long time, slow hydration of the magnesium oxide takes place with consequent expansion, and the rendering flakes away. In America the usual method of obviating the trouble is to hydrate the high magnesium lime under pressure, but as equipment for this is expensive and not available at present in Australia, an alternative method is being investigated. It is well known that magnesium oxide reacts readily with magnesium chloride or magnesium sulphate to give a hard, stable, magnesium oxy-salt known as "sorel cement", and it was decided to study the effect of adding these or related salts to high magnesium limes. Promising results have been obtained. Since it appears that the active agent is the chloride ion rather than the salts as such, investigations with other chlorides and hydrochloric acid are now being carried out.

(*d*) *Silica Brick Investigations.*—A proposal by a Western Australian firm to erect a sand lime brick plant was considered in detail. The lime plant and some sand deposits in the Perth area were visited. The lime sands used as a source of lime and the burnt lime have been chemically analysed and the slaking characteristics of the lime determined.

5. Clays and Clay Products.

(*a*) *Survey of the Heavy Clay Industry in Australia.*—The survey of the brick, tile, and pipe plants throughout Australia was continued and certain works making firebricks and refractory products were seen also. The industry in Western Australia was covered completely and most country yards in Victoria were visited. In New South Wales more works in the metropolitan area and clay and shale deposits to the west of the city and in the open-cut mines in the western mining district were inspected. Several works in South Australia, Tasmania, and Queensland were revisited and further consideration was given to the clay resources and the possibilities of expanding the brick and pipe industries in those States.

(*b*) *Clay Technology.*—Pilot-plant investigations of clays from all States in Australia have been continued. Although the plant is working to its full capacity, lack of staff is causing considerable delay in dealing with individual samples.

A property of "rubberiness", with which are associated certain unusual flow and drying characteristics, has been observed in certain clays during pilot-plant

investigations. This property, apparently related to the particle size distribution and especially to the high silt content rather than to the mineralogical composition, is being studied to determine its industrial significance.

(*c*) *Technical Advice.*—During the visit to Western Australia consideration was given to the modernizing of several of the brickworks in that State. Clays from these works have been forwarded to the laboratory for investigation and in one case a report has been prepared and recommendations made for complete reorganization of the works, including a change from the stiff-plastic to the semi-dry method for making bricks and the erection of tunnel kilns for firing them.

Consideration has been given also to the designs for new works in New South Wales and Queensland. Clays for these works are at present being tested. With the co-operation of Victorian State authorities, visits were made and advice on plant and equipment was given to several country works in Victoria. Visits have been made also to the State Tile Works in New South Wales and advice has been given on the steps to be taken to bring them into full production.

Owing to difficulties in obtaining adequate coal supplies, the question of firing kilns with oils is being raised repeatedly with the Division and advice on oil firing of ceramic kilns has been given to firms in Adelaide and Melbourne.

(*d*) *Clay Research.*—(i) *Distribution and Constitution of Clays.*—Much information has been collected on the raw materials of importance in the Australian heavy clay industry. They have been grouped on a geological basis.

An investigation of the mineralogical and ceramic properties of the clays of the Brisbane-Ipswich and Toowoomba areas in Queensland was completed by an officer of the Division during his tenure of a C.S.I.R.O. Studentship at the University of Illinois, United States of America.

(ii) *Expanded Clays.*—The importance of expanded, or "bloated" clays in the manufacture of lightweight terracotta ware and of lightweight aggregates for concrete has been recognized overseas in recent years, and a study of the bloating properties of Australian clays and the mechanism of the bloating process has been begun. The relevant literature has been surveyed and information on current investigations overseas has been sought. In all pilot-plant and laboratory investigations those clays that have shown a tendency to bloat have been noted. In addition, the work on the clays of the Brisbane-Ipswich area has shown some of them to be suitable for the production of expanded aggregates and a systematic sampling of these has now been made.

(iii) *Rehydration of Clays.*—The degree to which burnt clays may be hydrated has been suggested from time to time as a test for the completeness of burning of clay products. The behaviour after firing and subsequent treatment with steam of various "pure" clays and associated minerals is being studied. The physical and mineralogical changes undergone by the samples will be examined when the necessary equipment is available.

(*e*) *Terracotta Roofing Tiles.*—Tests on certain imported terracotta roofing tiles showed that they did not comply with the appropriate Australian Standard Specification in respect to strength and absorption. Results of wetting and drying and sulphate soundness tests show that the tiles should withstand normal weathering as well as local tiles do, but may be seriously affected in the vicinity of the sea by the crystallization of salts within the tiles.

6. Caulking Compounds.

(*a*) *General.*—Caulking or joint-sealing compounds has many applications both in buildings and in civil engineering structures where movement precludes the use of a rigid seal. Studies of these materials by the Division were undertaken to provide data necessary for an Australian Standard and to obtain information on the effect of composition on durability and the factors governing the choice of materials for particular applications. Initially a wide range of commercial products used in buildings was exposed to the weather at Highett and at the same time examined by simple laboratory tests with the object of relating performance to rapidly determinable characteristics. Useful results are now available. The original project has since developed into the formal study of the rheology of mastics generally and of miscellaneous problems associated with the sealing of joints in civil engineering structures.

During the year a documentary film covering certain aspects of this work was released.

(*b*) *Rheological Investigations.*—Rheological investigations are fundamental in the study of caulking or joint-sealing mastics whose efficacy is determined primarily by the manner in which they accommodate imposed stresses. Experimental work on the dependence of flow properties of oil-based compounds on composition has now been begun. So far investigations have related to the two-component system, mineral filler and vegetable oil.

(*c*) *Other Investigations.*—Assistance on the sealing of joints in flumes and race lines has again been given to the State Electricity Commission and the State Rivers and Water Supply Commission in Victoria. The large pneumatic caulking gun developed by the Division has been used extensively for these projects but it will need modification to make it suitable for continuous operation with automatic canal-lining machines. This will be done when information on the rheological properties of the mastic needed has been obtained. After preliminary trials a mastic based on a fatty acid pitch was recommended for use and the flow properties of this material are being investigated in the laboratory.

7. Concrete Floor Surfaces.

The purpose of the study of concrete floor surfaces is to determine the conditions necessary for concrete floors to be generally acceptable in domestic construction, the usual objection to them being that they are "cold and hard".

(*a*) *Physiological Investigations.*—(i) *Effect of Thermal Properties.*—In the previous Annual Report it was stated that a mathematical theory, based on certain simplifying assumptions, had been evolved to calculate the flow of heat between shod feet and the floor and that experiments for the purpose of checking the theory had been conducted on several subjects in various degrees of activity from sitting to brisk walking. When the results were analysed it was found that they were too variable to provide a precise check of the theory. It was also apparent that such experiments should be performed in cold weather when the subject's stored heat would be low enough for equilibrium to be reached in a reasonable time. Experimental work was, therefore, suspended until June, 1951.

Measurements have been made of the surface temperatures of a concrete floor in direct contact with the ground and surfaced in different ways. The maximum difference found was 1.5° C. between cork and bare concrete. No difference in the air temperatures could be detected 2 inches above the various surfaces.

(ii) *Effect of Mechanical Properties.*—Although the work previously reported on the measurement of the instantaneous pressures on the sole of the foot failed

to show any difference between various surfaces, studies of the deceleration of the head of a barefooted subject showed significant differences. This work is being extended to subjects in leather shoes.

(*b*) *Abrasion Testing.*—The examination of the characteristics of the widely used "Taber Abraser" has been continued. It has been found that misleading results are obtained if materials of widely different compositions are compared and methods of overcoming this disability are being investigated. To correlate laboratory measurements with behaviour in service, various floor-surfacing materials have been laid in a busy passage way.

8. Wall-surfacing Materials.

Methods of testing low-cost wall-surfacing materials for kitchens and bathrooms are being investigated so that their suitability and durability may be rapidly and reliably assessed. The mechanism by which soap damages paint-type wall surfaces is being studied also so that a knowledge of the way in which the materials fail will help in designing more resistant ones.

(*a*) *Mechanism of Attack by Soaps.*—Experiments have continued on the action of synthetic detergents on linseed oil paints, alkyd resin enamels, and a nitrocellulose brushing lacquer. These detergents, although of low alkalinity, were found to produce damage similar to that caused by soap solutions. The known ability of solutions of soap and synthetic detergents to dissolve water-insoluble materials plays a great part in the destruction of organic surface coatings, and consequently resistance to alkali does not necessarily mean resistance to soap. This is important in testing such coatings and in designing improved ones.

(*b*) *Laboratory Testing Methods.*—The cyclic soap spray cabinet has been used to examine commercial materials previously tested by normal laboratory procedures. Although most of the materials behaved similarly when tested in both ways, there were some conspicuous exceptions. This emphasizes the need for a better understanding of the physics and chemistry underlying the tests and breakdown in service. Work is continuing on the development of this method of test.

(*c*) *Experimental Installations.*—Experimental installations. (now two and a half years old) of polystyrene tiles have shown that they give reasonably satisfactory service. Gloss has deteriorated, but can be restored by rubbing the tiles with a soft cloth. However, failures of the adhesive are numerous and extensive. The adhesion has been poor on hardboard and asbestos cement sheet, better on plywood, and most satisfactory on plaster and plasterboard backings. Tests of available adhesives have been begun to provide data for the formulation of better ones.

Installations of factory lacquered hardboard of the same age are beginning to show signs of damage where they are exposed to steam and splashes of soapy water. The type of damage is similar to that observed in accelerated laboratory tests.

9. Bituminous Roofing Materials.

This study is of considerable interest to the building industry in Australia, since flat roofs in this country have the reputation of being subject to failure.

(*a*) *Field Survey of Flat Roofs.*—The survey throughout Australia to study construction techniques and to assess roof performance and the effect upon it of climatic conditions has been completed, over 150 roofs having been examined. The data are being analysed and incorporated into a report. It was found that roof performance was much improved when reflective or shielding treatments against solar radiation were employed, and that asbestos felts appeared to give considerably longer life than organic fibre felts. However, the waterproofness of flat roofs depends less on these factors than on the design and execution of the work and in particular on the treatment of flashings and other joints in the roof membrane. Here the standard of work seems often most inadequate and considerations of cost appear all too frequently to outweigh technical requirements. Comprehensive codes of practice are urgently needed in Australia and it is hoped that the report now in preparation may supply some of the data needed for them.

(*b*) *Laboratory Studies.*—Further study of the bond strength of laminates of various roofing membrane materials has confirmed that there is better adhesion between layers of saturated felts than between layers of bitumen-coated and mica-dusted roll roofings. It is hoped that analysis of the results of the field survey will show whether the susceptibility to blistering of built-up roof membranes is related to the degree of adhesion.

The properties of several grades of Australian-made bituminous roofings prepared with local and imported base felts have been studied and compared with those of roofings manufactured overseas. The Australian felts had saturation speeds and capacities lower than the overseas materials probably because the most suitable types of raw material are difficult to obtain in this country. Differences in distribution of the bituminous ingredients because of the different felt characteristics were noted. Samples of overseas roofings contained more saturant and less coating bitumen and were more flexible than Australian roofings of comparable weight.

Observation of surface temperatures and the behaviour on weathering of various experimental roof membranes constructed at Highett has been continued. The data have not yet been analysed, but the tentative conclusions previously reported have been confirmed. The maximum surface temperature observed was 184° F. on an untreated bituminous surface. The temperature of a similar surface painted with whitewash was 40° F. lower.

(*c*) *Experimental Roof Membranes.*—More full-scale trials have been made to allow pilot-scale evaluation of construction techniques and membrane materials. Aluminium foil has given particularly promising results, but its behaviour must be studied over longer periods of exposure before it can be thoroughly endorsed.

10. Heat Investigations.

The installation of two guarded hot-plate units for measuring the thermal conductivities of building materials is almost complete.

The literature on absorption and emission coefficients for solar and low-temperature radiation has been surveyed and the figures tabulated. As this has revealed that there are many gaps in the information available, equipment to measure coefficients will have to be installed.

The electrical analogue mentioned in the previous Annual Report has been wired and is being checked against theoretically known cases and thermograph readings taken during the summer in different types of houses. Mathematical investigations of the errors introduced by the necessary lumping of the electrical resistance and capacity have been made.

11. Architectural Acoustics.

The studies in architectural acoustics concern the acoustic behaviour of rooms and halls. Room acoustic designs are based on reverberation time theories, but even so the results are quite frequently unsatisfactory. Research is proceeding along two lines: the correlation

of subjective impressions formed by a listener with the measured properties of the sound wave, and the correlation of these objective properties with room shape and bounding materials.

Subjective experiments which entail measurements and observations of existing halls are at an early stage.

Correlation of objective measurements with room shape and materials has not been attempted experimentally because of the expense involved, and mathematical analyses are accurate only for rooms of regular shape. These difficulties could be overcome if it were possible to construct an acoustic model, i.e. create a space of smaller dimensions whose acoustics can be related to those of the full-size space. Theoretically this is possible if the model be at a scale of $1/n$, if the model frequency be n times that of the full size and if the bounding surfaces have equal impedances at the respective frequencies. This theory is being tested experimentally by using a room 44 feet by 16 feet by 11 feet as the full size and making a model on about one-quarter scale.

Acoustic impedances have been measured by the transmission-characteristic method described more fully in the previous Annual Report. By its use pairs of surfaces have been found which satisfy the criterion of having the same impedance at the different frequencies required in the acoustic model work.

12. Other Investigations.

(*a*) *Efflorescence.*—Work has continued on the study of the nature and mechanism of efflorescence on masonry walls. Additional samples of efflorescence and of aqueous extracts of masonry materials have been analysed.

(*b*) *Damp-proof Course Mortars.*—Investigations were continued on damp-proof course mortars to derive a standard specification for their performance. Progress was disappointing, but results so far indicate that the performance of these mortars as water barriers depends too much on variable factors such as brick suction and amount of mixing water to allow a standard to be formulated.

(*c*) *Under-floor Ventilation.*—An investigation of under-floor conditions in several recently constructed houses in Melbourne was made to determine the adequacy of ventilation and the part played by high under-floor humidity in promoting dry rot, internal dampness, and mould growth on walls and ceilings. In summer, relative humidities varying little from 80 per cent. were recorded under houses in conventionally ventilated floor spaces and during the autumn they rose as high as 90 per cent. It is therefore expected that under winter conditions the air under such houses may become saturated. On the other hand, the humidity in very well ventilated under-floor spaces has been found to be close to that of the atmosphere.

The investigations are being continued to see if the very high humidity necessary for the growth of dry rot does occur in winter and if high under-floor humidity influences conditions inside houses, and to find the minimum ventilation required to produce approximately atmospheric humidity under houses.

XV. WOOL TEXTILES.

1. General.

Research on wool production has been in progress in the Organization's laboratories for many years, and since the establishment of the Wool Textile Research Laboratories in Melbourne, Sydney, and Geelong, in 1950, the field of research has been extended to obtain information to enable wool to be improved as a textile fibre and to reduce costs of production of woollen, worsted, and felted materials.

Although difficulties have been encountered in procuring suitable laboratory accommodation and staff who have had the experience desirable for research on wool, some progress has been made. A property has been purchased for the Melbourne Laboratory near the University of Melbourne. Laboratory services are being installed and it is proposed to transfer from the present temporary quarters in Flinders-lane to the Royal Parade property late in 1951. The staff of the Sydney Laboratory, who were guests of various C.S.I.R.O. laboratories until June, 1951, are now temporarily accommodated in space provided by the Organization's Coal Research Section at Ryde, New South Wales. In August, 1950, the staff of the Geelong Laboratory transferred from the Gordon Institute at Geelong to new temporary quarters on the C.S.I.R.O. site at Belmont. Appreciation is again recorded of the co-operation of the Gordon Institute of Technology, not only in providing accommodation for the first few months of the year, but also in making available machines and equipment for use by officers of the Wool Textile Research Laboratories.

The opportunities for obtaining advanced training and research experience in fibre science in Australia are very limited, and it has therefore been necessary to recruit research staff from other fields. Some recent university graduates in physics and chemistry have been appointed to traineeships which will enable them to proceed to recognized textile research centres in the United Kingdom for intensive training before returning to positions in the Wool Textile Research Laboratories. Several years must necessarily elapse before the Laboratories are fully staffed with research workers adequately trained for the wide range of investigations proposed. In the meantime, however, it has been possible to extend the range of wool textile investigations in all three centres. One of the additional projects initiated in the Melbourne Laboratory concerns the fungal degradation of textiles. This research is allied to investigations already in progress on depilatory and other enzymes from moulds.

Following the return of the Officer-in-charge from overseas, the programme of research to be undertaken at the Sydney Laboratory has been defined more precisely. It covers the physical properties of fibres, with particular reference to wool, the physical properties and behaviour of assemblies of fibres, and the physical and engineering problems of fibre processing.

At the Geelong Laboratory new investigations include studies on combing and batching oils, bleaching, dyeing, and the jet process of solvent scouring.

In accordance with the policy of arranging frequent discussions between officers engaged in wool textile research in the Wool Textile Research Laboratories and in other Divisions of the Organization, the Second Wool Textile Research Conference was held at the Organization's Head Office in April, 1951.

A display of branding fluids, unshrinkable wool, and fellmongering methods was provided for the Centenary and Jubilee Exhibition held in Melbourne during March and April, 1951.

Owing to increased demand, the circulation of the Textile Newsletter from the Wool Textile Liaison Office at the Geelong Laboratory now exceeds 600 copies. There is a growing demand also for the Circular to Fellmongers which is issued from the Melbourne Laboratory.

In the account which follows, the work described in Sections 2, 4 (*b*), 5 (*b*), 9, 10, 11, 12 (*a*), and 16 was carried out at the Wool Textile Research Laboratory, Geelong, that described under Sections 3, 5 (*a*), 11 (*c*), 14, and 15 refers to activities at the Wool Textile Research Laboratory, Melbourne, and Sections 7, 8, and 12 (*b*) describe research at the Wool Textile

Research Laboratory, Sydney. Sections 4 (*a*), 6, and 13 describe projects under investigation at the Organization's Division of Industrial Chemistry.

2. Branding Fluids.

Laboratory and field experiments have been continued to improve the lanolin-base-emulsion (L.B.E.) branding fluid now being manufactured by many firms in Australia and overseas, and several firms have been assisted to overcome problems associated with its manufacture. A disadvantage of the L.B.E. fluid is that it tends to run if rain falls immediately after application to the sheep. Experiments are now in progress to overcome this defect, and encouraging results are being obtained with a modified preparation. During the 1951 shearing season this new product will be widely used in large-scale field trials.

Advice was also given to assist industry with the elimination of stains in woollen goods due to the presence of branding fluids not removed in normal processing.

3. Fellmongering.

Two processes have been recommended in the Organization's publications for the recovery of wool from sheepskin pieces and broken skins. Both require initial shrinkage of the skin tissues in hot water to promote subsequent digestion. In the first process, digestion is effected by soaking for eight hours in an extract of mould bran rich in proteolytic enzymes before continuing the digestion in warm water. In the second process, warm water is used throughout for the digestion, which depends solely on bacterial action. Owing to the high cost of producing the mould enzymes commercially in this country, the first process has had only limited application, but the second is becoming widely used with gratifying results. In some instances the quality of the wool recovered and the price obtained at auction have been equal to those of some of the best shorn wool.

Considerable interest in the new processes has been displayed not only in Australia but also in the United Kingdom and in New Zealand, and information concerning them has been provided for research workers and manufacturers in these countries.

Further work is in progress on the bacteriology of the water digestion process, primarily to determine whether methods can be developed to shorten or eliminate the lag phase in the water digestion process and thereby accelerate digestion. Conditions leading to bacterial discoloration of wool are also under examination, for a better understanding of the causes of discoloration should enable fellmongers to avoid this type of deterioration. It may also throw some light on the nature of the staining of wool which sometimes occurs on sheep in the field.

4. Scouring.

(*a*) *Low-temperature Scouring.*—The work on the low-temperature scouring of wool by the Physical Chemistry Section of the Division of Industrial Chemistry has continued. An attempt to use the process industrially failed because of the present trend towards using stearate soaps rather than those of the oleate type. The stearate soaps are not sufficiently soluble at room temperature to give a good scour. Alternative detergents other than the successful oleate are being tested.

(*b*) *Action of Scouring Liquors on Wool Fibres.*—The effect of scouring solutions on the elastic properties of single fibres has been studied. Contrary to general belief, it has been found that fibres do not show much decrease in strength after being immersed in a highly alkaline soap solution and then dried without rinsing. This indicates that wool is more resistant to alkali damage than was generally supposed.

5. Solvent Degreasing.

(*a*) *Drum Process.*—Reticulation of the pilot plant for testing the rotating drum solvent degreasing process at Maribyrnong is now complete. The plant has been tested for leaks, alternative methods of evacuating the system have been compared, and several of the components of the plant have been tested in preliminary trials. Difficulties in procuring suitable staff have delayed full-scale trials.

(*b*) *Jet Process.*—In April, 1951, work was commenced on a jet method of solvent-scouring which was originated outside the Organization. A large-scale combing trial is about to be carried out on wool processed by this method in comparison with similar wool processed by normal scouring. It is hoped in this way to obtain information on the relative merits of solvent-scoured and normally processed wool in combing and subsequent manufacture; there has been much speculation on this subject, but little experiment.

6. Wool Wax.

This by-product of the woollen industry has been studied further by the Organic Section of the Division of Industrial Chemistry. Its conversion into wax alcohols and acids by alkaline hydrolysis was examined to develop a simple method for this operation. The method has been shown to be suitable for the ready preparation of large quantities of wax alcohols. From these the valuable cholesterol was easily isolated and the remaining mixture of triterpenes and aliphatic alcohols has been the starting material for structural studies of these two groups of constituents.

The structure of the triterpene, lanosterol, is still unknown. Many methods to discover it have been tried, but only a few have shown promise and are being followed up. The work has resulted in the preparation of a number of new derivatives of lanosterol.

The structures of some of the aliphatic wax alcohols have been determined. After the trial separation of carnauba wax alcohols by the process of amplified distillation, these wool wax alcohols were submitted to similar treatment. As expected, they were less readily separated, but now a number have been isolated in a state of purity. They constitute a novel group of naturally occurring alcohols, closely related to the wool wax acids. Separation of wax esters by physical means is continuing.

In the Physical Chemistry Section of the Division of Industrial Chemistry wool wax is being recovered from scour liquors by an aeration (flotation) method. By controlling the temperature and pH value, more than 50 per cent. of the wax is recovered with simple equipment. This wax is free from dirt and soap. Scour plants will be able to use this process to produce salable wax from their discarded liquors.

7. Carbonizing.

Although carbonizing is a well-established process for removing vegetable matter from wool, the exact effect of the wide range of operating conditions and alternative treatment has never been properly investigated. In the early stages of this work attention is being restricted to the development of a method of measuring the effect of the carbonizing treatment on the wool and on the burr. A ballistic test is being tried to assess the wool damage and a machine is being tested which is designed to measure the "crushability" of burrs before and after carbonizing. Some mill tests have also been initiated on the effect of carbonizing with sulphuric acid on the felting of wool.

8. Wool Drying.

Wool is wetted and dried many times during processing. A thorough understanding of the physical laws governing the loss and addition of water is

necessary to the proper design of drying machinery and for process control. Experiments are being carried out in an effort to determine the most efficient way to dry wool without damaging the fibre. Interest centres on economy in time as well as economy in power. The work to date has been in the field of forced convection air-drying. Temperatures, rates of air flow, and methods of air circulation have been varied. It is clear that drying techniques should be dictated by the state of "dryness" it is desired to achieve. Water becomes more difficult to remove as complete dryness is approached and, although in the laboratory it is often necessary to reach a state of bordering on absolute dryness, requirements are not so rigid in industrial processes.

Other methods, including radiation, vacuum, and high-frequency drying, have not yet been examined. It is hoped to obtain information of a fundamental nature about the hygroscopic character of wool and its relation to the important thermal properties of wool textiles.

9. Yarn Manufacture.

A systematic study is being made of the action of textile lubricants in wool processing and some unexpected results have been obtained. It has been shown that products normally used, such as olive oil, modified mineral oil, and neatsfoot oil, do not act as lubricants but actually increase the friction between the wool and metal. Preliminary experiments indicate that friction between the wool fibres themselves is also increased.

10. Bleaching and Dyeing.

It has been found that peroxide bleaching is probably the most damaging of all the wet processes normally applied to wool, and research has been commenced to develop a less harmful method of improving the appearance.

Investigations have been carried out on low-temperature methods of dyeing which depend on the formation of colours by interaction between the chemical groups in the wool fibre and added chemicals. It was found that wool can be coloured in this way but, in most instances, the resulting shade is not fast either to washing or to light. So far, only one colour has been developed which gives a satisfactory fastness to light.

11. Chemical Modification of Wool.

(*a*) *Application of Resins to Wool.*—Studies have been continued on the application of resins to wool and their effects on the properties of the fibres.

Resins may be either applied to the fibres externally or deposited internally. An example of the former is seen in the modified nylon process for shrinkproofing wool fabric, which has been further developed during the year. In this process, the chemically-modified nylon is dissolved in ethanol and the fabric impregnated with the solution. The fabric is then dried, leaving a surface deposit of the nylon resin on the wool. On treatment with a dilute solution of acid, the modified nylon reverts to the original nylon, which is then able to prevent felting and shrinkage and also to increase resistance to wear. When using another type of modified nylon for impregnating the fabric, regeneration of nylon is accomplished by heat treatment.

The nylon impregnation process is being developed on a pilot-plant scale, and attempts are being made to combine it with the alcoholic alkali shrinkproofing process, since both treatments can be applied simultaneously in the one bath.

Other resins which may effect shrinkproofing of wool when applied as surface deposits are also being examined. In particular, the possibility of using wool itself as a shrinkproofing agent is being examined. Various methods of dissolving wool are being tested in an attempt to find one which yields a soluble product with little degradation of the keratin.

Attention has also been given to the internal deposition of various vinyl resins. It has been found that while wool can be made shrinkproof by depositing this resin internally, a much greater quantity of polymer is required than for surface deposits. An internal deposit of resin, however, reduces the elasticity and the ease of stretching the fibre. The harder the resin used, the more difficult it is to stretch the fibre.

(*b*) *Action of Shrinkproofing Reagents on Wool.*—A simple mechanical method has been devised for removing and collecting the scales from the wool and it is now possible to study in detail the action of shrinkproofing reagents on the scales and so detect minor chemical changes in the surface layers of wool fibres which may not be detected when the entire wool fibre is subjected to analysis.

Preliminary studies using this technique show that alcoholic alkali destroys all the cystine in the scales. Changes in other amino acids also result from treatment with sulphuryl chloride and chlorine, but the experiments are still in the preliminary stages. A micro-method for quantitatively estimating the amino acids in wool is being worked out in connexion with this investigation.

Experiments have also been carried out in collaboration with the Defence Research Laboratories on the establishment of an Australian standard for shrinkproofing woollen underwear. In this work, it has been found that a commercial washing machine of the horizontal cage type is almost as severe as milling stocks in producing shrinkage in wool. The methods used in most commercial laundries are also quite severe, whilst domestic hand-washing results in the lightest treatment of all.

(*c*) *Stabilizing Reactions.*—Research has been commenced on the use of certain types of organic compounds to introduce new cross-linkages into wool and it has been found that the moth-resistance of the modified wool is increased by some of the treatments used.

A new enzyme digestion method has been developed which permits the biological resistance of the chemically modified wools to be rapidly assessed. With this method, research on certain types of moth-proofing treatment will proceed more rapidly than when the effect of each modification could be assessed only by carrying out feeding tests with clothes moth larvae.

12. Physical Properties of Fibres.

(*a*) *Tensile Strength.*—The load-extension curve of wool fibres in water is often used to ascertain the effectiveness of certain treatments on the tensile properties of wool. However, as under normal conditions wool is mainly subjected to tensile alterations in air, it seemed desirable to ascertain whether there is any correlation between its tensile properties in air and those in water. The work required to stretch single fibres 30 per cent. in water was therefore compared with the breaking strength of the same fibres in air, and it was found that there was no correlation between the two results. This indicates that care must be taken in interpreting any results based on the former reading, which is often employed in assessing alterations in the strength of fibres due to different treatments.

(*b*) *Supercontraction.*—The contraction of a wool fibre to a length less than its original length under certain steaming and chemical treatments is referred to as "supercontraction". This physical change is of great importance in certain finishing operations which are applied to wool fabrics, such as blowing and shrinking. It is therefore proposed to learn as much as possible of the mechanism concerned. Supercontraction has been attributed to rupture of the disulphide bonds in the cystine cross-linkages and to cleavage of hydrogen bonds between the main peptide chains. To assess the relative importance of these two changes, lithium bromide is being used as the reagent to break hydrogen bonds and experiments are being carried out with wool from which amino groups have been removed, wool which has been permanently set, and wool which has been first supercontracted with reagents known to attack cystine, such as sodium bisulphite. The cortex and cuticle of the fibre are also being investigated in an attempt to discover whether one or both of the components are altered during supercontraction.

13. Protein Structure.

The study of the formation of fibres under natural conditions has been continued by the Chemical Physics Section of the Division of Industrial Chemistry. The conversion of soluble insulin into a fibrous form, and the production of silk by the silk worm, have been examined as examples of fibre formation analogous to, but more easily investigated than, the formation of fibrous keratin in the wool follicle. The findings support the view that the formation of elementary fibrils is an aggregation rather than a molecular spinning process. Knowledge of other fibrous systems has been extended by the study of a number of invertebrate muscles. The fine structure of these muscles was revealed and some information concerning muscle contraction was obtained.

Electron micrographs of surface replicas of wool fibres, showing the changes produced in the cuticle by shrinkage reduction processes and other forms of damage, have been prepared. An examination of the residues remaining after the solution of wool fibres showed that these always consist of the resistant fraction of the cuticle, i.e. the epicuticle with adhering protein.

A more detailed study of the iron-containing protein, ferretin, has been made possible by improvements which have been made to the electron microscope. The single molecule has been resolved and the location of the iron within it determined. The investigation has led to a better understanding of the uses and limitations of the metal shadowing technique.

Further work has been carried out on the X-ray structural analysis of α-amino acids, which are the building units of proteins. Detailed structure determinations have been completed for norleucine, proline, glutamic acid, and two forms of methionine. Other amino acids are being studied.

The synthesis of peptides and polypeptides likely to assist the study of protein structure by X-ray diffraction has been commenced.

14. Protein Chemistry.

(*a*) *Wool Fibre Investigations.*—As mentioned in the last Report, it will be necessary to learn as much as possible concerning the arrangement of amino acids in wool, for this will largely determine its physical and chemical properties. Progress has been made in the development of a new method of identifying the terminal amino acids, and already the application of this method to wool has yielded valuable results, but the application to wool of some of the procedures available for determining the physical and chemical properties of soluble proteins is severely limited by the insolubility of wool keratin. This had led to the study of methods of producing soluble products with minimum alteration of the structure of wool. One such method, which yields approximately 50 per cent. of the fibre in a soluble form, is to incubate wool in urea-bisulphite solution. Extracts obtained in this manner are being examined for molecular size, molecular shape, and light absorption in the ultra-violet region. Another method has been developed whereby the wool fibre is completely dissolved within a few hours in urea-bisulphite solution containing also a small concentration of a proteolytic enzyme. The peptides obtained by this second method are of smaller molecular size than those obtained by the first and will require the application of different methods of characterization. The improvement in the digestion of wool by proteolytic enzymes, resulting from the addition of urea and certain related compounds, points to a possibly important role of such compounds in wool damage by biological agencies and it also suggests a method for altering the surface properties of wool fibres sufficiently to improve their physical properties.

(*b*) *Peptide Investigations.*—Another method of studying wool chemistry is to join amino acids together to form peptides of the type which occur in wool and, by studying their properties, to assess which combinations of acids are likely to be responsible for some of the main characteristics of wool. These peptides will also be more suitable than wool for use in research on methods of modifying such structures. Several organic synthetic methods for the synthesis of peptides have been examined and it has been shown that, for certain types of peptide, the use of the phthalyl radical for covering the amino group of one amino acid before condensing it with a second amino acid is preferable to the carbobenzoxy method.

(*c*) *Wool Root Investigations.*—A third approach to the study of wool chemistry is through examination of the mode of wool synthesis in the wool root. It may be easier to determine the arrangement of amino acids in wool by learning how they are assembled and linked together at the site of synthesis than by studying the fully-formed fibre. The wool root investigations previously reported are therefore being extended, particularly by the application of histochemical methods.

(*d*) *Enzyme Investigations.*—A survey of the amino-acid compositions of a wide range of enzymes and of non-enzymic proteins has revealed certain relationships which distinguish these two groups from one another. These relationships suggest a mechanism for enzyme-substrate combination which will help to explain the mode of action of enzymes in the degradation of wool and other proteins.

Studies, now completed, on the effect of pH value and salts on the stability and activity of trypsin will enable conditions to be prescribed when using this enzyme in the degradation of proteins and peptides, which ensure maximum attack.

Research has been continued on the fractionation of enzymes in culture filtrates from the mould *Aspergillus oryzae* and from animal glands. Both mixtures contain depilatory enzymes capable of loosening the wool on sheepskins, and therefore, besides yielding information concerning methods of protein purification for application to the mixed products of wool degradation, the work should provide depilatory enzymes in a sufficiently pure state for use in wool root investigations. By investigating the mode of action of such enzymes on wool roots, valuable data concerning their structure and composition may be revealed. A major improvement in the enzyme fractionation research has been the development of a method for the complete removal of salts which have hitherto bound the enzyme molecules together.

15. Fungal Degradation of Textiles.

The rotting of cotton fabrics, a serious problem in hot, humid climates, is being investigated in an attempt to identify some of the underlying factors. If the nutrition of the major moulds concerned and the nature and mode of action of their cellulose-degrading enzymes are understood, it is expected that better methods of combating the damage will be developed than are likely to emerge from the empirical testing of fungicides on fabrics. Later, this research may be extended to deal with fungal damage to woollen fabrics.

The studies are being restricted initially to one of the most important cotton-damaging moulds, *Stachybotrys atra*. Suitable media have been developed for growing this organism in shake culture and methods have been devised for purifying and estimating those enzymes, such as cellulase, which are concerned in cellulose breakdown. Some of these purification procedures have been developed and tested initially against mixtures of enzymes produced by the mould *A. oryzae*.

16. Wool Textile Liaison Office.

The Textile Liaison Officer has spent six months visiting the United Kingdom, Europe, and the United States of America. During this visit arrangements were completed for the exchange of information with research organizations in various countries, and plans were discussed for dissemination abroad of the research results of the Wool Textile Research Laboratories. A review of textile research in progress in other countries was prepared and recent developments in textile machinery were examined.

Many inquiries from industry in Australia and overseas have been dealt with and several mills have been visited in connexion with process and machinery developments. The development of artificial fibres is being followed closely. Samples of the more important types are being collected and data assembled on their physical and textile properties. To meet the growing demands of the research and liaison office staff, the central reference library is being enlarged. Active representation on the textile committees of the Standards Association of Australia has been maintained during the year.

XVI. FLAX AND OTHER VEGETABLE FIBRES.

1. General.

Although concerned primarily with fibre from *Linum usitatissimum*, the Flax Research Laboratory of the Organization has extended its activities during the past year to investigations of a number of other vegetable fibres as well. The search for a local fibre of the jute type has been stimulated in Australia by difficulties in obtaining supplies from overseas of woolpacks, cornsacks, and hessian. There is also an acute shortage of sisal-type fibres for use in rope and in fibrous plaster manufacture. The Laboratory is assisting in efforts to develop local fibres by carrying out processing and manufacturing tests. It has a representative on the Central Fibres Committee, an inter-departmental body established to advise on proposed new fibre industries in Australia. The Laboratory is also closely associated with the Papua and New Guinea Fibres Committee, convened by the Department of Territories to assist in the promotion of fibre production in these areas.

The programme drawn up recently by the Commonwealth Government for the expansion of the Australian flax industry is now well under way. The Officer-in-charge of the Laboratory is a member of the Flax Production Committee (Department of Commerce and Agriculture) and also acts on a part-time basis as its consulting engineer. This arrangement ensures that the results of research carried out during the past ten years or so are available to the Committee in its work.

The activities of the Laboratory embrace a wide field of research, both fundamental and applied, extending from agricultural problems to investigations of processing and manufacturing. Grateful acknowledgment is made of the continued co-operation so readily given by the Flax Production Committee and by Australian flax spinners.

2. Agricultural Investigations.

The Flax Research Laboratory is assisting the Victorian Department of Agriculture in its programme of breeding disease-resistant flax varieties especially suited for Australian conditions. In addition to their resistance to rust, a number of the new strains produced have proved superior in fibre characters to Liral Crown, the variety generally sown in this country. The strains have been bulked to a stage where several acres can be planted this year; already straw from them has been processed and the fibre is being carefully tested for spinning performance.

By determining the yield and quality of fibre in the flax straw produced, the Laboratory has assisted in a number of agricultural field trials, including variety and manurial trials conducted by the Victorian Department of Agriculture and various sowing, harvesting, and variety trials conducted by the Flax Production Committee. During the last few years much information has been collected from such trials relating to the cultivation of flax in Australia.

Chemical analyses of leaf samples from a large number of growing crops have been made to determine the relationship between the amounts of various elements present and the yield and quality of the fibre in the crop. As a result of this investigation some special manurial trials are to be made this year with nitrogen and potassium.

3. Processing.

(*a*) *Water Retting.*—The applicability of the aerated method of water retting to Australian flax has been further demonstrated. In this technique air is passed through the retting liquor during the process, thereby controlling the acidity. As a result considerably faster retting takes place and the main liquor can be used over and over again, so that water supply and disposal problems are alleviated. The chief disadvantage lies in the fact that more careful supervision is required. The adoption of aerated retting at one flax mill in Victoria was recently agreed to by the Flax Production Committee and suitable equipment has been ordered.

Recent investigations of aerated retting at the Laboratory have been concerned with improved methods of aeration. Spinning tests showed that in all aspects of manufacture the fibre from aerated rets was at least equal, and often superior, to that from normal anaerobic rets.

Investigations aimed at improving the water retting of Australian flax by inoculating the liquor with pure cultures of especially active types of retting bacteria obtained from overseas have not yet been extended to the flax mills. Apart from problems associated with the initial building up of the large volumes of culture needed for inoculation, the fact that no ready means has yet been found to carry on the bacteria from one ret to the next makes large-scale operations impracticable at present. The emphasis of the work has, therefore, been shifted to more fundamental studies of conditions governing the growth of the retting bacteria, their nutritional requirements, and their metabolic activities.

(*b*) *Drying Retted Straw.*—In an effort to eliminate the tedious work of gaiting retted straw for drying, large-scale tests have been made at one of the flax mills with an improvised spreading machine which places

the straw flat on the ground in a uniform layer so that after drying it can be gathered mechanically by a pick-up binder. The test so far made has demonstrated that this method of drying would be practicable during summer at mills where a large field is available. However, before the spreading machine can be claimed to be entirely successful a number of mechanical alterations will have to be introduced. It is planned to extend the investigation next summer.

(*c*) *Scutching.*—While much of the inefficiency frequently associated with the scutching of retted flax straw results from the use of unskilled labour, much can be done in the way of mechanical improvements. A study is being made of the sources of the losses which occur during scutching and of various methods of eliminating them.

(*d*) *Preparing and Spinning.*—In addition to routine spinning tests carried out on fibre from agricultural and processing experiments, studies have been made of the effect of various modifications in the preparing and spinning technique on the strength and regularity of the yarn produced. For example, it has been shown that increasing the draft in gill spinning above a value of 12 has an adverse effect on the yarn. In preparing the fibre on the drawing frames, doubling has consistently been found to increase sliver regularity. Drafting does not improve the regularity of the sliver but simply increases the length of the thick and thin places. The effect of the direction in which the fibre is fed into the machines, whether butt first or top first, is now being investigated.

(*e*) *Boiling and Bleaching.*—Routine boiling tests are now given to the yarn from most spinning trials, accepted trade practice being followed. At the same time a working plan has been prepared and a preliminary series of investigations carried out to determine the effects of different boiling procedures on dry spun flax yarns, the measurements being made of strength, loss in weight, and change in colour of the yarn. The boiling agents so far used include various concentrations of soda ash, caustic soda, ammonia, and different wetting agents. A separate study of wetting agents has become necessary.

4. Utilization of Linseed Straw and Other Waste Materials.

Consideration has been given for some time to possible ways and means of utilizing various waste flax products. Included amongst these is the straw left when the seed is stripped from linseed crops, the straw from fibre flax crops which are of insufficient height to be purchased for normal processing, and the waste produced during deseeding.

The most promising avenue for the utilization of these products is the manufacture of paper or of low-grade yarns. One of the Australian paper companies is already experimenting with linseed fibre in paper production. The Flax Research Laboratory is conducting extensive investigations to determine the most economical method of obtaining fibre from these waste products in a form suitable for yarn manufacture.

5. Chemical Properties of Flax.

Investigations have been continued of the chemical composition of flax fibre, its effect on quality, and its relation to various processing methods. The constituents to which most attention has been given are lignin, pentosan, uronic acid anhydride, and mineral content. The technique of filter paper partition chromatography has been used to determine quantitatively the composition of the water extracts.

Determinations have been made of the acid values, saponification values, unsaponifiable matter, and iodine values of the wax from samples of Australian, Belgian, and Irish fibre. Earlier tests showed that the wax played an important part in determining the spinning quality of flax fibre.

6. Physical Properties of Flax.

(*a*) *Fibre Properties.*—The fineness to which flax fibre can be split during "hackling", or combing, determines the fineness of the yarn that can be spun from it. A study has been made of the way in which fibre bundles split into strands during hackling and of the type of fibre structure which permits this to occur most readily.

It has been shown that there is a statistically significant correlation between the behaviour of any fibre sample during preparing and spinning and the strength and fineness of the hackled strands. The relative merits of fibre samples can, therefore, be assessed in terms of these properties.

(*b*) *Yarn and Cloth Properties.*—Determinations have been completed on the relationships between the moisture content (regain) of Australian flax canvases and their strength. Equilibrium moisture content curves at various temperatures and humidities have also been established. This information is of particular value in specification testing.

7. Other Vegetable Fibres.

Investigations involving processing and/or evaluation of the fibre by means of physical and chemical tests have been carried out for various State and Commonwealth Departments on the following materials: Manila hemp, wild banana, kapok, coir, kenaf, ramie, plains grass, canna, and jute.

XVII. INDUSTRIAL CHEMISTRY.

1. General.

The Organization's chemical research is undertaken mainly by the Division of Industrial Chemistry, which has its headquarters at Fishermen's Bend, Victoria. In addition to the work of the Division described in this Chapter, investigations on wool scouring and wool wax are described in Chapter XV., work on flotation minerals in Chapter XVIII., and work on the utilization of low-rank coal in Chapter XIX.

Chemical research relating to problems of various industries is also undertaken in several other Divisions and Sections, and is described in the Chapters relating to those industries.

In the Report for 1949-50 some major projects of the Division were outlined. During the year under review substantial progress has been made on these and other projects.

Though the headquarters of the Division are in Melbourne, 20 officers work in other parts of the Commonwealth. In Sydney a High Pressure Laboratory is now established within the Chemical Engineering Department of the University of Sydney, and the results of some early investigations are being published. This laboratory is well equipped and its resources are being used by officers of the University of Sydney in collaborative investigations with members of the Organization's staff. In addition, funds were made available to the University to award two scholarships. The recipients are receiving training in high-pressure techniques while working for higher degrees.

In Adelaide, in conjunction with the School of Mines and Industries and with the support of the South Australian Government, the Division operates a Ceramics Research Laboratory. It also has an officer

working in the School of Mines and Industries on analytical problems that have arisen in connexion with the uranium ores of South Australia.

In Perth, officers are working in the Chemistry Department of the University on vacuum ultra-violet spectroscopy, the chemistry of alunite, with a view to its better utilization in the production of potash fertilizers, and the physiologically active alkaloidal principle of the Dwalganup strain of subterranean clover, a pasture plant injurious to sheep.

Apart from officers working on Divisional projects in other parts of the Commonwealth, several are seconded to other Divisions for work for which they possess special qualifications.

The volume of publications from the Division has increased rapidly in recent years because of the substantial progress made in many of its long-term projects, and about 70 papers were sent to various journals during the year under review.

At the suggestion of the Chief Executive Officer a conference was held on modern physical methods in biology. It was attended by about 60 representatives of other Divisions and Sections, mostly the biological ones, and aroused great interest in the application of the methods of chemical physics to the solution of biological problems.

Within the Organic Section steps have been taken to provide a more comprehensive microanalytical service for scientific institutions and industry. An Advisory Committee has been set up, consisting of Professors E. J. Hartung and V. M. Trikojus, of the University of Melbourne, and the Chief of the Division, to advise the Organization on the policy it should adopt in providing this service, which, through the generosity of Professor Hartung, occupies excellent temporary accommodation at the University of Melbourne. Already the service has been freely used by the Universities and by industry, and determinations are being made at the rate of over 200 each month.

2. Minerals Utilization.

There are many deposits of minerals in Australia which, although of great potential significance because of their extent and high quality, have so far been developed industrially to only a very limited extent. In many instances where the naturally occurring mineral is used as such, local supplies have differed in some particular from those which have long been imported, and the successful use of the local material is dependent upon some form of preliminary treatment or the modification of the process in which it is used. In others, the minerals, even when improved in grade by physical processing, have only a comparatively low market value, and their potentialities can be fully realized only through their conversion to valuable derivatives by chemical processing. Examples of the first type are the Australian sources of graphite and manganese dioxide, which after comparatively simple treatment have been found to fulfil all requirements for use in the manufacture of dry cells. Examples of the second type are the widespread deposits of the rare earths of the cerium group, which have few uses as such compared with the great variety of industrial applications of the derivatives obtained by chemical treatment. The research programme of the Minerals Utilization Section is based on the development of new methods of processing and the fundamental study of the chemistry of the constituents of a number of minerals in order to extend the range of their derivatives and their industrial applications. The projects have been so planned that the techniques and the results of one may be used in the development of another. For example, the study of the chemistry of the rare earths has proved valuable not only in the processing of minerals of which they are the major constituents, but in their separation as useful by-products in the recovery of the major constituents of other minerals. In the search for new avenues of exploiting our mineral resources, the strategic importance of replacing imported mineral products which might cease to be available to this country has been borne in mind. The trends of current work are indicated below.

(*a*) *Monazite.*—Work on monazite has been continued with the object of effecting improved separation of the rare earth components and thorium. A cyclic fractional precipitation process has been devised which permits relatively pure cerium and lanthanum compounds to be separated from mixed hydroxides derived from monazite. In addition a mixed nitrate product containing other rare earths, which is suitable for their separation by fractional crystallization or ion exchange techniques, has been produced.

The rare earths have been separated from thorium by the chlorination of monazite at high temperatures. Under these conditions thorium chloride volatilizes and the dry molten chlorides of the rare earths which remain are free from all major contaminants except calcium and magnesium. This work has now been completed. A study has been made of the chemistry of stable complex compounds of the rare earths and certain organic compounds. These complex derivatives are being used to separate a number of the rare earths by fractional crystallization, fractional precipitation, or ion exchange.

Work on the recovery of thorium from monazite has been continued and has necessitated a chemical study of a number of thorium derivatives.

(*b*) *Zircon.*—The abundance of zircon in the beach sands of southern Queensland and northern New South Wales and the ever-growing importance of zirconium, of which zircon is the chief ore, provide a strong incentive for research on this Australian mineral. Special attention has been paid to the separation of the closely associated hafnium from the zirconium, and two new methods of effecting this separation have been developed. One of these processes is particularly applicable to the production of large quantities of hafnium-free zirconium and application has been made for a patent covering this process. At the same time small quantities of pure hafnium oxide are being isolated.

(*c*) *Graphite.*—The highly conducting graphite from South Australian deposits, if finely ground and purified, has already been shown to be suitable for use in normal dry cells. In recent tests it has been found to be of particular value in cells required to deliver heavy currents of short duration, for example in synchronized flash photography. A comparison has been made of the behaviour of a range of cells containing either acetylene black or natural graphite, covering all those met with in practice. As part of the work on the classification of graphites, determinations of the proportions of the isotopes of carbon have been made with the object of throwing light on their age and origin. Fundamental studies of the properties and reactions of a graphite-ferric chloride complex have been extended, and it has been discovered that stable complexes containing a high proportion of chromium are also formed between graphite and chromyl chloride or chromyl fluoride.

(*d*) *Manganese Dioxide.*—The behaviour of the manganese oxides and of other oxides used in galvanic cell systems has been examined and comparisons have been made on the basis of their physical and thermodynamic properties. Studies of the causes of shelf deterioration in dry cells containing manganese dioxide have begun. Work has continued on the determination,

by X-ray analysis, of the manganese mineral cryptomelane. Its structure has proved to be more complex than other manganese oxides and has not yet been elucidated. The manganese-oxygen system has been studied in an attempt to relate the various structures with chemical reactivities.

(*e*) *Uranium.*—The programme of work on the extraction of uranium from the low-grade titaniferous ores from Radium Hill, South Australia, has been intensified, and flow sheets, operating details, and costs have worked out for two alternative processes by which the uranium could be satisfactorily recovered. One of these processes, which involves acid treatment of the ore and selective solvent extraction of the resulting liquor, has been chosen because of the simplicity of the plant required and its relatively low operating costs. Considerable progress has been made with the laboratory investigation of this process and its development on a pilot scale has been commenced. The staff was augmented during the year to accelerate both the laboratory and chemical engineering aspects of this work. This ore is a complex one and besides uranium, it yields several very useful by-products.

3. Cement and Ceramics.

The programme of the Cement and Ceramics Section is made up largely of investigations of a long-term character, but testing work and other short-term projects are undertaken when the Section has special facilities not available elsewhere. In this way it has been able to help governmental bodies and manufacturers by giving advice, by examining and testing materials, and by processing materials in the laboratory. Some new investigations have been begun but are severely limited by the acute shortage of laboratory accommodation.

Practical and financial assistance has been given by the Cement and Concrete Association of Australia to the Section's cement investigations and by the National Gas Association of Australia to the work on gas retort refractories.

(*a*) *Cement-aggregate Reaction.*—The work in this investigation, which is concerned with deterioration produced in concrete by expansive reaction between the aggregate and certain constituents of the cement, is being extended into a number of different fields. The action of reactive aggregate particles in expanding concrete specimens is being studied in order to increase the precision with which the probable behaviour in practice of cements and aggregates can be evaluated. The action of superincumbent load on the expansion of mortar is also being investigated. This investigation has much significance in the study of the behaviour of massive structures affected by cement-aggregate reaction. Additional work has been done on the properties and treatment of pozzolanic materials that can be used for correcting cement-aggregate reaction.

From the cement-aggregate reaction problem have evolved an investigation of crack development in cement paste, mortar, and concrete, since the incidence of cracks has important applications in studies on concrete durability, and an investigation of the classification and reactivity of various types of silica.

The radioactive tracer technique can be applied to the study of some of these problems. Initially it has been necessary to develop methods of handling and preparing specimens. Attention is now being given to studying the movement of radioactive sodium in cement pastes and mortars, and in reactions between silica and sodium hydroxide.

(*b*) *Pozzolanas.*—Methods have been evolved for evaluating pozzolanic cements. Much preliminary work has been done on the properties and behaviour of pozzolanic mortars. These studies have given much information about the strength development and durability of different mixes. Several pozzolanas, representative of all the main types, are being investigated.

(*c*) *Surface-active Agents in Cement and Concrete.*—Possible improvements in the durability of concrete brought about by the entrainment of minute bubbles of air are being investigated. The mechanism of entrainment of air in cement pastes is at present being studied. Air entrainment cannot be explained entirely as being due to changes in the properties of the liquid part of the system. Equipment is being made for studying the durability of mortar and concrete.

(*d*) *Cement Clinker Investigations.*—The main investigation on laboratory clinkers of controlled alkali content is now regarded as complete and the results have been published. However, clinkers of special composition have been made and cements have been prepared from them as part of a collaborative investigation with the Melbourne and Metropolitan Board of Works.

(*e*) *Mineralogical Studies.*—Recently work on phase equilibria of a number of different systems has been recommenced. The systems that are being investigated should give valuable information on the constitution and chemistry of cement clinkers, cement kiln refractories, and various metallurgical slags, for example, basic slags from Bessemer and open-hearth furnaces.

(*f*) *Refractories Investigations.*—A critical study of Australian gasworks refractories is in the press. It describes the after-expansion contraction and other characteristics of these materials, possible methods for improving the performance of the refractories, and the temperature distribution and fluctuation in an operating gas retort. An investigation of the behaviour of gasworks refractories in the presence of heavy steaming has been started. Study of the mechanical and chemical factors which influence the durability of cement kiln linings has continued and attention has also been directed to the fabrication of stabilized clinker bricks for use in such linings. A report has been made on a peculiar slagging problem arising in the boilers of a powerhouse of the State Electricity Commission of Victoria.

(*g*) *Clay Investigations.*—An extensive account of the ceramic clays of South Australia is in the press. A comparable study of Western Australian clays is well advanced. Clays from a number of other sources have been submitted to the Section and have been examined when their probable industrial value appeared to justify the investigation. Study of the rheological and other colloidal properties of clays has continued. It has involved investigation of anion absorption and problems in the deflocculation of clays for casting purposes. Part of this work is being continued by one of the officers concerned at Rothamsted Experimental Station in England during the tenure of an overseas studentship. Some attention has been given to the possibility of markedly enhancing the plasticity of certain Australian kaolins.

(*h*) *Silica Investigations.*—The ceramic properties of Australian silica from a number of sources, usually novel, have been studied. A fundamental investigation of the effects of heat on microcrystalline silica (flint) has revealed new points of interest.

(*i*) *Whiteware Investigations.*—The investigation of the changes which occur during the fabrication and firing of whiteware has been continued, particularly with respect to the factors affecting porosity. Attention has also been given to the effect of shaping processes on the microstructures of clays and bodies and to the succession of changes occurring during the fusion of granite fluxes. These investigations are designed to assist in the utilization of ceramic materials from unfamiliar sources.

(*j*) *Saggar Investigations.*—Saggar compositions developed from South Australia and other materials continue to give excellent results in service and an attempt is being made to develop compositions requiring an initial firing temperature lower than that originally employed.

(*k*) *Special Ceramics.*—A study of certain titanate dielectrics has begun.

(*l*) *Adelaide Laboratory.*—This laboratory is maintained in collaboration with the South Australian School of Mines and Industries. A wide variety of ceramic raw materials has been examined and recommendations for utilization have been made. These investigations have been referred to the laboratory by the South Australian Department of Mines, other Government bodies, and manufacturers. A technical Advisory service has been maintained and has been much in demand by industry.

4. Foundry Sands.

Throughout the year the foundry industry has continued to use to full advantage the consulting and advisory service provided by the Foundry Sands Section. Frequently it has been possible to reply to inquiries from the accumulated experience of the staff of the Section. Sometimes limited programmes of experimental work have been undertaken to supply the information upon which replies have been based. The advisory service has covered the whole field of foundry practice and has not been restricted to matters involving foundry sands.

Surveys of sand deposits have been continued with the object of maintaining an up-to-date catalogue of the sands available in each State. In Victoria this work is being undertaken in collaboration with the Department of Mines.

Further studies of the behaviour of sand cores have been made in an endeavour to develop improved organic core binders. The properties of Australian bentonitic clays have been investigated to provide data for their application in place of imported bentonites for production of synthetic moulding sands.

5. Physical Chemistry.

The chemistry of surfaces continues to be the chief subject of investigation in this Section, with particular reference to the flotation process by which mineral concentrates are separated from ores, and to the allied problems of detergency. A study of the efficiency of heat transfer in industrial condensers has commenced.

(*a*) *Flotation Investigations.*—The work on flotation, which includes the study of two practical problems of ore concentration, and fundamental work on the physical processes affecting the efficiency of flotation machines are described in Chapter XVIII., Section 4.

(*b*) *Detergency.*—The low-temperature scouring of wool described in the previous Report has been tested on a larger scale. This work and a flotation method of recovering wool wax from scour liquors are described in Chapter XV., Sections 4 and 6.

(*c*) *Steam Condensation.*—The efficiency of industrial condensers is partly limited by the transfer of heat across the thin stagnant layer of condensed water which forms on the cooling surface. If a water-repellent surface is formed on the condenser, the steam condenses as droplets instead of as a film. The resultant increase in the amount of the highly conducting metal surface of the condenser which is exposed to the vapour phase brings about a substantial improvement in the efficiency of the condenser. Recent work has been directed to the retention of the water-repellent film, which is at present the chief practical difficulty.

(*d*) *Flotation and Surface-active Agents.*—Inquiries about these subjects from industry and other groups in the Organization continue to occupy a considerable amount of time.

6. Chemical Physics.

The Chemical Physics Section has continued its work on four main projects: protein structure investigations; the development of new and improved techniques; chemico-physical studies of the solid state; and the determination of molecular structures. In addition, work has been carried out on problems submitted by industry, medical institutions, the Universities, and other Sections of the Organization. Nine guest workers from other laboratories have worked with the Section for various periods and it has been gratifying to welcome the large number of visitors who wished to see the Section's equipment and discuss its possible application to their particular problems.

(*a*) *Protein Structure Studies.*—Details of this work, which forms part of the Organization's wool research programme, are given in Chapter XV, Section 13.

(*b*) *Development of Chemico-physical Techniques.*—Progress in pure and applied science depends to a large extent on advances in experimental technique. An important part of the Section's programme, therefore, is the improvement of existing chemico-physical methods and the development of new ones.

(i) *X-ray Microscopy.*—When fully developed, this technique will be of great importance, particularly in the determination of the distribution of various elements in biological materials. Work on the design of X-ray microscopes has progressed, and a new method for overcoming many of the difficulties encountered in the recording of the image has been devised and is now being tested.

(ii) *Mass Spectroscopy.*—Mass spectrometers of novel design are being developed. These will be inexpensive and of great value in analytical work.

(iii) *X-ray Diffraction.*—A new type of specimen-holder for use at high temperatures has been designed, and its construction is almost complete. It will be used for the determination of the structures of metals and the study of metal-gas systems at high temperatures.

(iv) *Electron Diffraction.*—Although the resolution obtained with the camera developed by the Section compares favorably with that obtained with the best cameras yet developed elsewhere, this instrument is now being modified to give even higher resolution. A second and more versatile camera, incorporating an electron miscroscope, is under construction and will be used for studying the structures and shapes of ultra-microscopic crystals.

(v) *Electron Microscopy.*—Modifications which have been made to the Section's R.C.A. electron microscope have resulted in such a high resolution that little further improvement in performance can be expected from this type of instrument.

(vi) *Spectroscopy.*—A simple method has been developed for converting a conventional monochromator to a multiple monochromator having much higher resolving power and a negligible amount of scattered radiation. This invention promises to have a lasting influence on experimental spectroscopy. It will permit more accurate spectroscopic analysis and lead to much new information on molecular structure.

The machine for ruling echelette zone plates, which are to be used in a far-infra-red spectrometer, is nearing completion. The study of far-infra-red spectra will lead to much valuable information regarding the structure of large molecules, such as proteins.

A vacuum spectrograph designed and constructed in the Section is now located in the Chemistry Department, University of Western Australia, where an officer of the Section is working in collaboration with Professor N. S. Bayliss on studies of far-ultra-violet spectra.

(vii) *Luminescence.*—A periodic excitation phosphorometer, designed in the Section, has been constructed and is being used in an investigation of the mechanism of luminescence.

(*c*) *Chemical Physics of the Solid State.*—Studies of the solid state have been concerned with: (i) phenomena due to crystal lattice defects; (ii) properties of the surfaces of solids, particularly those associated with the intrusion of gas into a metal surface; (iii) small particles whose properties differ markedly from those of the bulk solid.

(i) *Defect Solids.*—Structural defects are responsible for many important properties of materials, including those which make possible such articles as fluorescent lamps, certain types of radio valves, television screens, and dry rectifiers. They are also important in problems of catalysis and in many other processes. The phosphorometer is being used to study the mechanism of luminescence processes, the understanding of which is essential to studies of the structure and properties of defect solids.

(ii) *Surfaces of Solids.*—The structure of the surfaces of solids is important in problems relating to lubrication, bearings, catalysis, and the flotation of minerals. Basic information concerning surface structure has been obtained by electron-diffraction studies of the structure of gold surfaces after heating in air and in krypton.

(iii) *Electron-diffraction Studies.*—The high resolution obtainable with the Section's electron-diffraction camera has enabled much new information to be obtained regarding the shapes and structures of very small crystalline particles. Electron-diffraction studies of caesium gold chloride have led to an explanation of the unique properties of dual-valency co-ordination compounds.

(*d*) *Molecular Structure Investigations.*—The determination of molecular structure is fundamental to most problems in chemistry, biology, and biochemistry. Physical methods offer the best approach to accurate structure determinations. Examples of the Section's work in this field are given below.

(i) *X-ray Crystallography.*—As part of the protein structure programme, the structures of α- and β-methionine and copper proline have been determined. Analyses of the structures of norleucine and glutamic acid is almost complete, and progress has been made in the structure determination of other amino acids. Work on the structure of dihydrolanosterol, an important derivative of wool wax, is progressing satisfactorily. Other structures analysed include potassium hydroxy chlororuthenate, potassium hexafluoroplatinate, cryptomelane, and priderite, the last two in collaboration with the Minerals Utilization Section.

(ii) *Infra-red Spectroscopy.*—The infra-red studies of porphyrins and their derivatives have been completed. This work forms a useful contribution to the understanding of the biochemistry of blood pigments. The structures of organic disulphides and related compounds have been investigated. A new interpretation of the ozone spectrum has been suggested. Infra-red spectra have made an important contribution to the theory of solvent effects.

(iii) *Electron Diffraction.*—The Section has pioneered the application of electron diffraction methods of structure analysis. This technique provides the only method to determining the structures of surface compounds and microcrystalline material. Structures which have been determined include γ-alumina, gold-oxygen systems, and dicetyl.

(iv) *Mass Spectroscopy.* — The fully-automatic apparatus for determining appearance-potential curves has yielded data which made a valuable contribution to our knowledge of chemical and molecular structure.

(*e*) *Service Work.*—The specialized techniques of the Section have been applied to problems submitted by other laboratories and by industrial organizations. Among the problems studied are the following:—

(i) *Electron Microscopy.*—Investigation of the morphology of acetylene black and graphite, examination of carbon from sucrose, soil colloids, thorium oxalate, thorium oxide catalysts, and myxoma virus. This virus, which is important in rabbit myxomatosis, has been identified under the electron microscope and measurements have been made from the electron micrographs of the size and shape of the particles. This investigation is proceeding and it is hoped that it will be possible to establish the presence of the virus particles in insect or other vectors.

(ii) *X-ray Diffraction.*—Characterization of the phases in iron oxide used in the purification of coal-gas, detection of talc in mica used for plastic fillers.

(iii) *Spectroscopy.*—Investigations of the structures of alkaloids, hydrindone derivatives, the bitter principle of citrus fruits, a resin degradation product, clays, inositol and related compounds; analysis of alumina, thorium oxide, chromium, glaze on fired sillimanite, cassiterite, rare earths, penicillin pigments; determination of diffuse reflectance spectra of paint films.

(iv) *Electron Diffraction.*—Examination of ceiling plaster, flint, corroded copper cables, lithiophorite, and lead chromate.

(v) *Mass Spectroscopy.*—Determination of the ratio of carbon isotopes in graphites; identification and estimation of purity of products of deuteration studies; identification of weed taint compounds; determination of ratio of oxygen isotopes in carbon dioxide; analysis of apple respiration products.

(*f*) *Instrument Laboratory.*—Several major items of equipment have been designed and constructed by the mechanical, electrical, and glass-working shops for this and other Sections of the Division. In addition, a large amount of repair and maintenance work has been carried out.

7. Organic Chemistry.

The work of this Section has been chiefly directed to the study of wool wax and sugar-cane wax, which are both potentially of economic importance; the study of the alkaloids of Australian flora, some that give rise to diseases in stock and others that might have useful therapeutic and other properties; a study of the mechanism of the phenol-formaldehyde condensation; and the further investigation of products which can be obtained as the result of reaction between acetone and ammonia.

(*a*) *Wool Wax.*—The study of this by-product of the woollen industry has been continued with the object of isolating the wool-wax alcohols and determining their structures. A more detailed account of this work will be found in Chapter XV., Section 6.

(*b*) *Sugar-cane Wax.*—Several thousand tons yearly of this wax are potentially available from the solvent extraction of the filter muds from cane-sugar mills. A refining and bleaching process was described in the previous Report. It involves removal of undesirable constituents by heating under reduced pressure and bleaching by chromic acid, and gives a hard pale yellow wax which is essentially a mixture of higher fatty acids. The cost of producing this bleached wax

has been estimated as closely as is possible from laboratory data and it appears that it could be sold at a competitive price. In attempts to convert this wax into a series of ester waxes, much unexpected difficulty has been met. Although it is readily esterified with simple monohydric alcohols, only incomplete esterification has so far been effected with polyhydric alcohols, which should yield wax esters of greater value to the wax industry than sugar-cane wax.

(*c*) *Alkaloids.*—The programme of stock poison investigations outlined in the last Report is being widened to include *Atalaya hemiglauca,* which is presumed to be responsible for the so-called "Kimberley" disease of horses, and *Indigofera enneaphylla,* which has recently been identified as the cause of "Birdsville" disease of horses. Considerable progress has been made with the development of a paper chromatographic method for the quantitative study of variations in the alkaloid content of *Heliotropium europaeum,* and the structure of lasiocarpic acid, the major esterifying acid of the alkaloid lasiocarpine, has been determined. It has been established that the toxic principle of the cycad *Bowenia serrata* is the nitrogenous glycoside macrozamin.

The bark of the Australian commercial timber tree *Balanops australasica,* which gives rise to nasal irritation, has yielded two triterpenes, one identical with friedelin (from cork) and the second, not previously described, a dihydrofriedelin. Tests by Associate Professor Shaw of the Department of Physiology, University of Melbourne, have shown that neither possesses to any marked degree the irritant properties characteristic of the timber and, in fact, this property has been located in a water-soluble fraction.

The investigation of the alkaloids of Australian Rutaceae has been continued. Work on the alkaloids of *Pentaceras australis* has been completed and two of the three members of this new group have been synthesized. Further work has confirmed the structures allotted to the pyranofuranoquinoline bases acronidine and medicosmine, which are derived from other members of the Rutaceae, and some interesting features of their chemistry have been brought to light. The ultra-violet absorption spectra of these and of other furanoquinoline alkaloids are being studied in collaboration with the Chemical Physics Section. The alkaloid of *Gyrocarpus americanus* has been identified as phaeanthine by comparison with an authentic specimen isolated from *Phaeanthus ebracteolatus.* Work is continuing on the vesicant alkaloid cryptopleurine. Unfortunately the amount present in the bark is much less than was at first thought.

(*d*) *Plastic Investigation.*—(i) *Kinetics of the Phenol-formaldehyde Condensation.*—An investigation is being made of the phenol-formaldehyde reaction which is the basis of the phenolic resin industry. However, in order to study the phenol-formaldehyde reaction under alkaline conditions it is necessary to study the exact course of a simultaneous reaction involving formaldehyde and alkali. This has been achieved by preventing the phenol-formaldehyde reaction by the use of a phenol which does not react with formaldehyde. Having determined the course of the formaldehyde-alkali reaction, allowance can be made for it when it occurs simultaneously with the reaction between formaldehyde and phenol. By this means it has been possible to measure the rate of the latter reaction. The phenols used in resin manufacture react with several molecules of formaldehyde, but in the present investigation the reaction has been simplified by the use of phenols which can react with only one.

(ii) *Adhesives of Tannin-formaldehyde.* — The tannin of *Pinus radiata* bark is easily extracted and has proved to be very active in adhesives of this type. Its properties differ slightly from those of mimosa bark tannin, necessitating modifications of the adhesive formula and particularly of the methods of gluing. Modifications are still being made, but an adhesive has been prepared which gives a waterproof bond in plywood if set at about 100° C.

(*e*) *The Reaction between Acetone and Ammonia.*—Whereas at temperatures up to room temperature the product of this reaction is, as already reported, a pentamethyl pyrimidine, it has now been found that at higher temperatures entirely different products result which are derivatives of dihydropyridine. These can be selectively hydrogenated first to tetra- and then to hexahydropyridines, making possible a ready means of transition from cheap reagents to heterocyclic bases of potentially useful classes. A detailed study of these compounds and their method of formation is in progress.

8. Chemical Engineering.

Applied and fundamental research has been continued with the object of obtaining design data for industrial operations and processes, particularly in the fields of adsorption, fluid properties, fine particles, and the utilization of low-rank coals.

The advisory service to chemical industry has been continued, as well as the provision of facilities for the design and construction of equipment for other Sections of the Division.

During the year the facilities of the Section were made available to twelve guest workers, most of whom were seconded from industry to investigate particular problems of the industries concerned.

(*a*) *Development of Adsorption Processes.*—Work has been continued on the development of a continuous fractionating process for the separation of the components of solutions by adsorption on carbon and other adsorbents. The investigations have been centred on the separation of antibiotic materials and the treatment of industrial effluents. Methods have been developed for obtaining continuous counter current flow between the solid adsorbent phase and the solutions, and these methods have been applied to both continuous and batch fractionating processes. The successful operation of these fractionating procedures has required the development of new methods for accurately controlling and measuring small flow rates for both solids and liquids.

The officer in charge of this investigation spent part of the year in England and America studying developments in adsorption processes.

(*b*) *Fluid Properties.*—The application of many engineering design procedures is dependent on a knowledge of the values of the physical properties of fluids and of their variation with temperature and pressure. To assist in overcoming the general lack of such values and of methods of predicting them, the Section has continued investigations to determine precise liquid and vapour equilibrium concentrations for binary mixtures, and other physical properties of fluids, and the manner of their variation with change in temperature or pressure. In the former work values have been obtained for the binary system cyclohexane-nitrobenzene at 80° C. and 760 mm. pressure. Apparatus has been developed for equilibrium measurements on systems having high relative volatility. Equipment has also been constructed for the precise determination of heats of mixing.

The methods of statistical mechanics have been used in a theoretical study to evaluate the thermodynamic functions, firstly for a one-dimensional array and subsequently for a three-dimensional array, of alcohol molecules in a binary mixture of an alcohol and a non-polar liquid. This theoretical study has given

results which are similar to those obtained experimentally, and shows promise of providing a means of predicting the thermodynamic properties of solutions of this type. This work has formed part of the programme of the Section's recently established high-pressure laboratory, where a new method permitting greater precision has been developed for the determination of the second virial coefficients of gases. These coefficients represent the magnitude of the initial departure of gas from ideality and provide data for determining intermolecular forces. Values of the coefficients have been determined for chloromethane, fluoromethane, *cyclopropane*, and *n*-butanol.

Equipment and methods have been developed for the study of the effects of solvation on the dipole moments of molecules in solvents of low dielectric constants. In this connexion determinations have been made of the dielectric constant of ethylene over a range of high pressures and of solutions of chloromethane in ethylene as a solvent gas up to pressures of 500 atmospheres and at temperatures of 25° C. and 50° C.

Work has been initiated, and equipment designed and partly constructed, for the determination of Joule-Thomson coefficients for several gases. These determinations provide an alternative experimental route for the determination of second virial coefficients and of thermodynamic properties. By such determinations it is hoped to co-operate with overseas laboratories in the preparation of charts of thermodynamic properties of industrially important fluids and fluid mixtures.

The synthesis of certain minerals is being attempted at high pressures and temperatures.

Some work has been done on developing methods for studying the solubility of inorganic salts in gases subjected to high pressures.

The recent award by the Organization of a research fellowship for post-graduate study in the High-pressure Laboratory has allowed an investigation of the thermodynamic properties of ionic solutions to be begun.

(*c*) *Fine Particles.*—The separation of finely divided solids from either gas or liquid suspensions is a problem common to many industrial processes. The observed behaviour of beds of fine particles when flocculated or compacted can be related to industrial filtration problems. Results obtained from research with dilute suspensions have been applied in the design and construction of a centrifugal dust and mist separator, in which it is expected that small particles may be separated for a low power consumption.

(*d*) *Process Equipment Laboratory.*—Additions and modifications to the pilot-scale processing equipment have been made during the year to improve the service this laboratory provides for other Sections of the Organization and for the chemical manufacturing industry.

XVIII. MINERAGRAPHY AND ORE-DRESSING.

1. General.

Mineragraphic work to provide information on the mineral composition of ores has been in progress in Melbourne since 1927. Ore samples are also examined, in co-operation with the Mining Department of the University of Melbourne and with the School of Mines, Kalgoorlie, to determine the most suitable methods of treatment. This work is described in Sections 2 and 3 of this Chapter.

Work in the Division of Industrial Chemistry on the flotation of minerals is described in Section 4. Other work in that Division on the utilization of Australian minerals is described in Chapter XVII., Section 2.

2. Mineragraphy.

Twenty-nine investigations have been carried out into the mineral association of rocks, drill cores, and mill and smelter products submitted by mining organizations and institutions. Some of these were related to the search for new mineral deposits and some were concerned with the experimental treatment of ores in the Ore-dressing Laboratories.

The examination of a copper zinc ore from the No. 9 mine, Drake, New South Wales, disclosed the difficulties involved in the separation of copper and zinc. The zinc blende in this ore was deposited with a little chalcopyrite in solid solution which was discharged on cooling as minute inclusions of chalcopyrite. The chalcopyrite was deposited with a little zinc sulphide in solid solution which precipitated and migrated during cooling to the margin of the chalcopyrite, coating it with a film of zinc blende. Further difficulties were caused by a little secondary copper enrichment in which zinc blende has been rather selectively replaced by chalcocite with the result that chalcocite is sometimes intimately associated with unreplaced residuals of zinc blende.

Analogous difficulties are encountered in a silver-lead-zinc ore from Bauloora, near Cootamundra, New South Wales. The galena extends as threads and veinlets along hair-line cracks ramifying areas of massive zinc blende. The galena also has a pronounced tendency to form rims 1-2 microns wide around grains of zinc blende and chalcopyrite.

Pyritic ore from Nairne, South Australia, yields a pyritic concentrate containing both pyrite and pyrrhotite. The amount of pyrrhotite is 15½ per cent. of the free sulphides in the 56-micron-sized fraction, increasing to 27 per cent. in the 20-micron-sized fraction. The overall sulphur content of the concentrate indicated that the particles less than 20 microns in size, which constitute nearly a quarter of the concentrate, contain a still higher percentage of pyrrhotite.

An experimental zinc concentrate from the North Broken Hill mine contained an abnormally high silver content which was found to be due to an unusual amount of pyrargyrite. The silver was located in composite grains containing dyscrasite, tetrahedrite, or pyrargyrite, the last of which was distinctly the most abundant and important.

An examination of manganiferous slags from the Newcastle Steel Works was made as a contribution to a programme of investigation for the recovery of manganese. The slags consist of a silicate phase and an oxide or "wustite" phase. Phosphorus occurs in the silicate phase and while manganese occurs in both phases, it is conceivable that such manganese as occurs in the "wustite" phase could be separately relatively free from phosphorus. The problem would require the modification of the composition of the slags to promote the formation of the "wustite" phase.

An initial study of the hematite quartzites of the Middleback Ranges has shown that they consist of magnetite, hematite, some limonite, and quartz, in distinctly iron-rich and quartz-rich bands without any clean-cut separation. The iron-rich bands contain as much as 30 per cent. quartz intimately intergrown with the iron minerals and all the quartz-rich bands contain some proportion of iron minerals. Magnetic concentration of the iron minerals is not likely to be satisfactory, but gravity separation might be effective.

The examination of primary uranium ore from Rum Jungle and Fergusson River, Northern Territory, has disclosed the occurrence of the primary uranium mineral, uraninite, for the first time in Australia. The uraninite occurs in small masses and strings up to 3 mm. across which tend to enwrap pyrite crystals or

appear in quartz or slate between masses of chalcopyrite with its associated minerals. Sometimes the uraninite is associated with oriented intergrowths of chalcopyrite and cubanite, derived from a chalco-pyrrhotite solid solution, and sometimes it occurs as a meshwork of thin veins surrounding quartz grains. It is also found as strings and clusters of rounded grains up to 0.025 mm. across in chalcopyrite veins. Evidence of veining of these rounded grains by chalcopyrite indicates that the uraninite was earlier than the chalcopyrite. At Fergusson River, cobaltite occurs in the chalcopyrite veinlets.

The investigations have been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has also co-operated in providing laboratory accommodation in the recent extensions of the Geology Department.

3. Ore-dressing Investigations.

Work done at Melbourne in co-operation with the Department of Mining of the University is recorded in twenty reports. Of these, six refer to tin ores, five to gold, two to beach sands, and one each to silver, manganese, antimony, gypsum, soil, brown coal, and clover seed. Of 21 investigations in hand but uncompleted, six are concerned with tin ores and three with wolfram. Electrostatic separation with or without magnetic separation has been applied to beach sands, tin concentrates, brown coal, and other products.

Examinations of gravity concentration of tin from a large low-grade ore body in New South Wales have been made.

Investigations to determine the reasons for incomplete recovery of gold in a large Western Australian plant treating a low-grade ore have been carried out.

The mining industry's demand for the ore-dressing investigations that are being carried out in co-operation with the Kalgoorlie School of Mines continues. During the year much attention was given to gold ores, particularly dumps and complex ores involving various difficulties in their metallurgical treatment. There was also a marked demand for help with other metals, particularly lead and silver ores. Tests were undertaken, for instance, in connexion with the concentration of a dump of lead-containing minerals. Requests were also received for assays of wolfram ores.

4. Flotation Investigations.

In the Physical Chemistry Section of the Division of Industrial Chemistry a satisfactory method of concentrating topaz (used in ceramic ware) has been devised. This mineral is extremely sensitive to salts dissolved in the water used in the flotation process. Work has continued on the separation of the tungsten mineral, scheelite, from King Island ore. No economic method has yet been found, and much of the difficulty appears to be related to the nature of the froth produced in the flotation operation. The surfaces of frothed solutions are, therefore, being studied by means of a new surface viscometer, and high-speed photography is being used to study the collapse of the froth walls. The cells of a froth are formed from single bubbles. These collapse more readily than does an aggregate of bubbles and, being simpler, are more easily studied. However, no simple correlation has been found between the factors which alter the time of their collapse and the behaviour of frothing agents.

XIX. FUEL.

1. General.

Research on Australian coals undertaken by the Coal Research Section at Ryde, New South Wales, is reported in Sections 2 and 3 of this Chapter. An investigation of fossil pollen in brown coals, which is being made on a co-operative basis in the Botany School of the University of Melbourne, is reported in Section 4.

The Chemical Engineering Section of the Division of Industrial Chemistry, Melbourne, is carrying out a programme of research on the utilization of low-rank coal, and this is described in Section 5.

Coal Research Section.—This Section was formed for the purpose of making a fundamental and comprehensive study of the physical and chemical characteristics of Australian coals, in order to provide essential data for research into new uses and improvements in present-day uses of coal, and to establish a sound basis for the rational distribution and utilization of the national coal resources.

Preparatory work and the training of staff have proceeded throughout the year in the limited space of a small temporary laboratory, but the work has been seriously hampered by difficulties in obtaining staff and delays in completing buildings commenced in October, 1949.

The temporary laboratory is still situated in an area made available by the Commonwealth Experimental Building Station of the Department of Works and Housing, and the Section is deeply indebted to the Director of the Station.

The Officer-in-charge attended the British Commonwealth Scientific Official Conference on Fuel Research in London in July, 1950, and was appointed chairman of the session dealing with synthetic fuel and chief co-ordinator for physical testing, petrographic, and brown coal investigations.

Changes in personnel have delayed both the petrological and the carbonization investigations, but some progress has been made.

Photomicrographs of spore types from several seams have been prepared and various techniques connected with spore separation have been studied.

2. Examination of Coal Seams.

(*a*) *Lithgow.*—A survey of the Lithgow seam, the major seam in the New South Wales western coalfield, is being pursued in the detail necessary to provide a comprehensive picture concerning trends in physical and chemical properties over the area of its known occurrence. Three pillar sections and one borehole core of the complete seam have been sampled and examined. Although it is essentially a steam coal, suitable for locomotive and industrial use, in the south of the area pronounced coking properties are in evidence and have justified the carrying out of pilot-scale carbonizing tests.

(*b*) *Callide.*—A section of the Callide seam from the Callide open-cut mine, Queensland, comprising the full height of 57-58 feet, has been examined in detail by division into 37 sub-sections. The seam is of sub-bituminous rank with an inherent moisture content exceeding 10 per cent. Owing probably to the immature nature of the coal, some difficulty was experienced in the identification and subsequent separation of the banded constituents, especially clarain and durain.

(*c*) *Bulli.*—Pillar sections covering known variations in height and structure of the Bulli seam in the Burragorang Valley district of the southern New South Wales coalfield have been taken and tests have confirmed the pronounced coking properties of this seam in this area. Coking is associated mainly with bright coal content and, because of the greater friability of this constituent and its concentration in the fines below ½-in. particle size, a separation into a coal of excellent coking properties and a steam or industrial fuel of only moderate coking properties appears possible merely by screening.

3. Analysis of Brown Coal.

Samples of earthy and lignitic brown coal have been obtained from the Yallourn open cut, Victoria, for the purpose of determining the general applicability of British Standards Institute methods of analysis to coals of such low rank. Analytical variations due to the storage of samples are also being investigated. Minor difficulties have been experienced in obtaining accurate weight balance during carbonization assays, owing largely to the high carbon dioxide content of the gas, and also in the determination of mineral (pyritic) sulphur, and these are being investigated. In general, however, the work so far done indicates that the British Standard methods may be satisfactorily applied to the analysis of brown coal.

4. Microstructure of Brown Coal.

Studies on fossil pollen in brown coal deposits have been continued on a co-operative basis in the Botany School of the University of Melbourne. An investigation on the genera *Araucaria* and *Agathis* was completed and work has been started on a fossil Cycad.

5. Utilization of Low-rank Coal.

During the year the erection of the laboratory, workshop, and office accommodation for the programme of research of the Chemical Engineering Section of the Division of Industrial Chemistry into the utilization of Australia's low-rank coals was completed. At present research is directed toward the development of methods for the complete gasification of Victorian brown coal for the production of gas suitable for the synthesis of liquid fuels and chemicals, and of gas of high calorific value suitable for distribution as town gas.

As a result of a preliminary investigation of the gasification of brown coal and brown-coal chars in a small-scale fluidized bed, a new fluid-bed gasification unit has been constructed which incorporates numerous improvements. It is hoped that this unit will provide quantitative data concerning the influence of the operating variables on the performance of fluid-bed gasification systems. Preliminary designs have also been prepared for a further pilot plant in which the effects of operating pressures of up to 20 atmospheres will be investigated.

Considerable progress has been made in the study of the kinetics of the gasification reactions of brown-coal chars, and in particular in the study of the catalytic effects of the ash constituents of the coal on the water gas shift reaction. An investigation of the clinkering behaviour of the coal ash is also in progress.

Research into the production of a high calorific value gas has progressed to the stage of design and partial construction of experimental equipment for operation at pressures of up to 50 atmospheres.

An investigation of the carbonizing behaviour of brown coal in a fluid bed is nearing completion.

XX. PHYSICAL METALLURGY.

1. General.

The Section of Physical Metallurgy is still housed in the Baillieu Laboratory in conjunction with the Research School of Metallurgy in the University of Melbourne. Its main work has consisted of a study of the metallography of the alloys of titanium with metals of the first transitional period, gas surface reactions of titanium, and the influence of prolonged stress on lead alloys. Advantage has also been taken of the development of new metallographic techniques to introduce them in the laboratory, in conjunction with the Physics Section of the Defence Research Laboratories.

2. Titanium and its Alloys.

(*a*) *Effects of Alloy Elements on Allotropic Transformation.*—By means of the hydrogen pressure method, the behaviour of the allotropic transformation was studied in alloys of pure titanium with vanadium, chromium, manganese, iron, cobalt, and nickel respectively as far as 5 atomic per cent. It was found that the temperature was depressed by all these elements. Thus all are shown to have appreciable solid solubility in β titanium but very low solubility in α titanium.

(*b*) *Age Hardening of Iron-titanium Alloys.*—Following the constitutional work on iron-titanium alloys, further work has been done on the changes in mechanical properties of alloys containing 6-10 per cent. iron by age hardening treatments. Although not hardened by quenching, they respond to a subsequent heat treatment between 350 and 450° C.

(*c*) *Effects of Oxygen Addition.*—The behaviour of the allotropic transformation of titanium on addition of oxygen was studied by a thermo-electric method and by metallographic techniques. It was shown that the temperature is appreciably raised by 5 atomic per cent. (1.75 wt. per cent.). The influence of oxygen on the mechanical properties was also studied. It was found that 1-1.5 atomic per cent. increases the tensile strength by 10-20 tons/sq. in. but there is a corresponding loss of ductility.

(*d*) *Kinetics of Gas Reactions with Titanium.*—The absorption of oxygen and other gases by titanium has led to an investigation of the kinetics of gas reactions with this metal at various temperatures. In view of the great reactivity shown at temperatures over 500° C. it is important to know how titanium and its alloys will react under the high-temperature conditions under which this metal may be used.

(*e*) *Analytical Methods.*—In connexion with this alloy work, it has been necessary to develop methods for chemical analysis. The object has been to avoid the separation of large amounts of titanium from the solution. Photo-electric colorimetric methods have been developed for the estimation of silicon, iron, manganese, chromium, nickel, cobalt, and copper in solutions containing large amounts of titanium. A satisfactory method of determining oxygen in these alloys by removing the metal with chlorine has also been developed. Further work is proceeding on the extraction of titanium cupferrate from aqueous solution using chloroform in order to facilitate estimation of aluminium, calcium, and magnesium.

(*f*) *Electrolytic Extraction of Titanium.*—An important contribution to the extraction metallurgy of titanium has been made in conjunction with a research student in the School of Metallurgy. Metallic titanium was produced by the electrolysis of titanium trichloride dissolved in a molten halide mixture. Main difficulty in the development of this process is the chemical one of reducing efficiently the tetrachloride to the trichloride.

3. Creep of Lead Alloys.

This work has continued on lines previously outlined. The complex relationship between thallium content and creep rate is still being studied. These alloys are yielding data which will help to elucidate the mechanism by which slow deformation under stress takes place.

The methods of phase-contrast microscopy and multiple-beam interferometry, and the use of polarized light, have been developed and are yielding useful results.

XXI. TRIBOPHYSICS.

1. General.

Division of Tribophysics.—The work of the Division during the past year has been a continuation of that described in last year's Annual Report. Understanding of the causes of friction has advanced and it has become clear that the surface properties of a metal exert a greater effect on the process of sliding than do the bulk properties. For this reason the group which was formerly investigating the frictional behaviour of metals is now studying surface properties of solids.

The development of the work is still hindered by lack of space. Construction of the new laboratory has begun, but in the meantime the Division is still using the facilities of the Chemistry Department of the University of Melbourne. Sincere thanks are due to the University and to Professor Hartung. The active co-operation of the Chemistry, Metallurgy, Physics, and Engineering Departments of the University has greatly assisted the Division.

Co-operation with the Chemical Physics Section of the Division of Industrial Chemistry has continued. As the electron diffraction camera has arrived and is now operating in the Division of Tribophysics, the officer working on the structure of lubricating films on metals has returned from the Division of Industrial Chemistry. The Division has continued to give assistance and advice to many industrial organizations and Government and University Departments in the fields of lubrication, bearings, metallurgy, electrolytic polishing and plating, surface chemistry, and electronics. Members of the Division are acting on various technical committees, in particular on the Engineering Group Committee. The metallurgical colloquia held with other metallurgical groups in Melbourne continue to attract large attendances.

2. Properties of Surfaces.

The frictional forces between sliding metals arise mainly from the shearing of junctions and, to a small extent, from the ploughing of the slider through the stationary surface. As the asperities on which the two metal surfaces make contact are covered by oxide layers, the possibility of a metal-to-metal junction being formed depends on the thickness, strength, and brittleness of the oxide. When the junctions are broken during sliding the free metal surfaces oxidize again immediately. On repeated sliding oxide particles are broken off the surface and become deeply embedded in the metal as it suffers turbulent deformation. Hence, the bulk properties of the sliding metals influence the friction only to a small extent, and a further study of the behaviour of metal surfaces is required.

Apart from investigations on some practical aspects of friction and lubrication, the work is now mainly concerned with the properties of surface films of long-chain compounds and the surface tension of solids. Experiments are also in progress on the catalytic activity of single crystalline surfaces and the properties of silicone lubricants.

(*a*) *Bearing Testing.*—The test equipment has been further developed for more precise evaluation of bearings under a wider range of operating conditions. Tests on white metal bearings have shown that maximum load-carrying ability and minimum friction are obtained only with very careful alignment and highest geometric accuracy of manufacture.

(*b*) *Piston-ring Lubrication.*—The stability of the oil film between piston ring and cylinder wall is being investigated by continuous measurement of the electrical resistance of the film. It has been shown that under normal engine operating conditions the oil film is maintained even in the presence of very small quantities of oil, although breakdown always occurs at top and bottom dead centre. The most adverse condition occurs in starting from cold, when petrol condensation on the cylinder walls may completely rupture the oil film for several minutes.

(*c*) *Spreading of Liquids on Solids.*—The mechanism and rate of spreading of various oils over clean polished metals and the influence of small concentrations of long-chain polar compounds are being studied. Experiments indicate that adsorbed water films present on the surfaces may influence considerably the rate of spreading of an oil.

(*d*) *Adsorption.*—The formation of surface films of polar long-chain substances on solid surfaces by adsorption from solutions is being investigated by direct measurement. Owing to the great difficulties associated with the removal of contaminants from the surface of metal powders, oxides are now being used. A study of the adsorption isotherms at different temperatures will provide information on phase changes in adsorbed films of various compounds.

(*e*) *Surface Tension of Solids.*—A knowledge of the surface energy of solids is required for the understanding of the sintering of metal powders and the geometric structure of polycrystalline metals. The surface energy of metals is being determined by measuring the change in length of fine wires suspended under known loads at high temperatures. Wires a few thousandths of an inch thick extruded in vacuum are maintained slightly below the melting point and the load is noted which just balances the contraction due to surface tension.

(*f*) *Electrolytic Polishing.*—Although electrolytic polishing is widely used in industry and research, its basic mechanism has remained hitherto obscure. Experiments have shown that polishing is due to the formation of an oxide film at the metal surface. This is covered by a viscous liquid layer of products of electrolysis. It follows that the surface of an electrolytically polished specimen is always contaminated with oxide.

The demand for the manual on electrolytic polishing issued two years ago continues, and the Division answers frequent inquiries from industry and research laboratories on electrolytic polishing methods.

3. Metal Physics.

The work on metal physics is concerned with the plastic properties of metals and with the mechanism of phase changes. Greater knowledge in these two fields will make it possible to state the optimum conditions of a material for various applications in practice.

(*a*) *Plastic Deformation.*—The plastic deformation of metals occurs mainly by slip within the crystals, and it is now generally assumed that slip takes place through the motion of a particular type of lattice defect —the so-called dislocation. However, no direct evidence of the existence of dislocations and of the connexion of their movement with slip is as yet available. For these reasons the problems of slip and work-hardening are being attacked experimentally from various angles, with the particular aim of learning more about the lattice defects and their density and arrangement after deformation.

(*i*) *Shape of X-ray Interference Lines.*—The lattice distortions produced by deformation manifest themselves by a broadening of the lines in X-ray diagrams. In order to obtain information on the details of these distortions, the exact shapes of the lines have to be known. Techniques used previously have yielded unsatisfactory results because monochromatic radiation was not used. With strictly monochromatic radiation the intensities become very small and necessitate the use

of Geiger counters. The Geiger counter spectrometers built in the Division fulfil all the requirements and work satisfactorily. From the line shape the energy associated with the lattice distortions can be calculated and this is correlated with values obtained by direct measurements.

(ii) *Measurement of Energy Stored in a Metal During Deformation.*—This energy is liberated on annealing the metal and can be measured as the difference in the specific heats of deformed and undeformed specimens. As the difference is small relative to the specific heats, an apparatus of extremely high accuracy is needed. A differential method is being employed. A differential milli-wattmeter and automatic temperature controllers keeping temperature difference within 1/10° C. have been constructed. The accuracy of the results is about 5 per cent. compared with the 20 to 30 per cent. obtained by previous observers. Effects of grain size of the metal, type of deformation, and previous history of the specimen, formerly inaccessible to measurement, can now be observed.

(iii) *Change in Electrical Resistivity due to Cold Working.*—Wires of several metals and alloys have been drawn at various temperatures ranging from — 183° C. to + 100° C. and the resistivities measured at these temperatures. The higher the temperature of deformation the smaller is the increase in resistivity, since the dislocations are more mobile and can diffuse more readily out of the crystal. When the resistivity is plotted against temperature, the curves for the annealed and the deformed wires are very nearly parallel. The analysis of these results in terms of number and distribution of dislocations has still to be carried out.

(iv) *Deformation of Two-phase Alloys.*—The relative deformations of the phases in duplex brass have been studied over wide ranges of deformations and proportions of the two phases present. Wire drawing was used as the method of deformation and the temperature at which recrystallization begins was used as an index of the degree of deformation. In alloys containing more than 30 per cent. by volume of the hard phase, crystals of both phases deform to the same extent for total deformations of up to 80 per cent. reduction in area. In alloys containing 10 and 20 per cent. by volume of the hard phase, the heavier deformation always occurs in the softer phase, although the difference in deformation of the two phases becomes less as the total deformation of the brass increases beyond about 50 per cent. reduction in area.

(v) *Recrystallization.*—The growth of the new crystals in deformed specimens during recrystallization has been followed using polarized light. The fact that the growth is erratic suggests a reason for the hitherto unexplained observation that the rate of nucleation increases with annealing time. Because of the non-uniformity of the rate of growth, the period during which a growing nucleus remains too small to be observed will be very variable. Only a certain fraction of these nuclei will grow to an observable size in successive units of time. The number of unobserved nuclei will increase with time if the true nucleation rate is constant, and hence the apparent rate of nucleation will increase with time.

The reasons for the erratic growth are still not clear, and further experiments are in progress in an attempt to correlate the inhomogeneity of deformation with the mode of recrystallization.

(b) Phase Changes.—There are two ways in which a phase change in solids can occur. First, it may involve nucleation and growth of the nuclei, in which case thermally activated diffusion is the fundamental mechanism. Secondly, the rearrangement of the atoms may occur in such a way that each atom has the same neighbours in the new structure as it had in the old, no interchange in the position of neighbouring atoms having taken place. The second type of change occurs extremely rapidly, and proceeds only during cooling of the alloy. As the hardening of steels (formation of martensite) is due to this type of transformation, its practical importance can hardly be overrated.

From various observable features, particularly the change in external shape during the transformation, the movement of the atoms can be deduced. This has been done for steels and some alloys by one of the Division's officers while on a Studentship in Chicago. The technique developed during these investigations is now being used to find the atomic movements in transformations which produce changes in external shape of the specimens, although they occur by thermal diffusion. The order-disorder transformation in copper-gold and the precipitation in supersaturated copper-beryllium alloys are being investigated and it seems that the mechanisms by which nucleation-growth and "martensite" transformations occur may not be as fundamentally different as first thought.

4. Reaction Kinetics.

The kinetics group has been concerned mainly with two problems, a study of the kinetics of oxidation of organic compounds and the measurement of thermal conductivities of organic vapours.

Work is also in progress on the reactions of free radicals with gaseous hydrocarbons and on the kinetics of decomposition of organic peroxides.

(a) Kinetics of Oxidation Reactions.—Reactions of organic substances with atmospheric oxygen are commonly used in industrial processes. They also cause the deterioration of numerous materials, for example, lubricants and rubber.

The experimental study of the kinetics of oxidation is being pursued by two methods, each of which is designed for the examination of a single step in the reaction mechanism.

(i) *The Oxidation of Aldehydes in Solution.*—The oxidation of benzaldehyde to hydroperoxide in the presence of a peroxide catalyst occurs by two simultaneous but distinct chain reactions, one of which is initiated by the catalyst. The other reaction is of special interest in that, though a chain reaction, it appears not to involve free radicals.

(ii) *The Oxidation of Simple Hydrocarbons in the Gas Phase.*—A technique has been developed for the observation of the kinetics of the first stages of the oxidation. The kinetic behaviour in these circumstances is considerably simpler than that which obtains when the reaction has become fully developed. Observations on the effects of inert gases on the rate of development of the reaction have afforded some insight into the reaction mechanism.

A new theory of the kinetics of hydrocarbon oxidation has been proposed which accounts for a number of the experimental facts relating to the complex behaviour of the reaction in its more advanced stages.

(b) Thermal Conductivity of Organic Vapours.—The extent to which organic molecules are associated in the vapour phase is being studied by measurements of thermal conductivity at various pressures. With molecules in which no association is possible, the pressure dependence of the thermal conductivity is sight, but vapours of molecules which may be expected to associate show a more pronounced increase in thermal conductivity with increasing pressure. From these measurements it is possible to determine the association constants and heats of association for various molecules.

XXII. NATIONAL STANDARDS LABORATORY.

The National Standards Laboratory was founded in 1938 as a result of the Commonwealth Government's decision to extend the activities of the Council for Scientific and Industrial Research to secondary industry. The Secondary Industries Testing and Research Committee, set up by the Government to prepare a plan for this extension, recommended *inter alia* that a National Standards Laboratory be established to maintain the physical standards of measurement for the Commonwealth and to provide means for the calibration of secondary and working standards. These subsidiary standards are a fundamental requirement for the effective development of secondary industry, particularly in those branches in which high precision and interchangeability of parts are essential. The Committee's report also pointed out that the establishment of a National Standards Laboratory would enable the Weights and Measures administration of the various States to be based on Commonwealth standards, as was the wish of the 1936 Conference of Commonwealth and State Ministers.

The Laboratory was established in the grounds of the University of Sydney and is now able to meet most of the requirements of industry and governmental and semi-governmental authorities for the calibration of sub-standards and precision measuring equipment in terms of internationally recognized standards of measurement.

Legal status is given to the standards of measurement maintained by the National Standards Laboratory by the *Weights and Measures (National Standards) Act* 1948, which makes the Organization the custodian of the national standards of measurement. Under this Act the States continue the administration of Weights and Measures matters affecting trade and commerce, and the States' standards of measurement are derived from the Commonwealth standards of measurement maintained by the National Standards Laboratory. The Commonwealth legal units and standards of measurement are defined in the Regulations to this Act, which also provides for a National Standards Commission to advise the Commonwealth Government on Weights and Measures.

The statutory functions of the National Standards Laboratory in maintaining standards, testing, and calibration are carried out by the Divisions of Metrology, Physics, and Electrotechnology, in the following special fields:—

Metrology.—Length, mass, time, and the physical quantities directly derived from these, such as area, volume, force, and pressure. The needs of industry in these fields inevitably involve this Division in certain aspects of applied mechanics.

Physics.—Heat, which involves maintaining the International Temperature Scale; light, including candle-power, luminous flux, illumination, colour measurement; viscosity; the primary electrical standards of resistance and voltage.

Electrotechnology.—Resistance and voltage other than the primary standards, capacitance, inductance, power, frequency, magnetic quantities, the maintenance of standards of measurement of these quantities for both direct and alternating current over the range used in industry and in research.

The three Divisions of the Laboratory carry out research in matters directly related to the maintenance of standards and precision measurement, and also provide an important service to industry by giving advice on methods of measurement and by investigating special problems. The Divisions also engage in research of a more fundamental kind. Details of the work of the constituent Divisions are given in the following three chapters.

XXIII. METROLOGY.

1. General.

Division of Metrology.—As a part of the National standards Laboratory, the Division of Metrology is responsible for the Commonwealth Standards of measurement of length, mass, and time, and the associated physical quantities. Much of the work of the Division during the year has been directed towards meeting its statutory obligations.

The universal comparator has been installed and is meeting all requirements. The geodetic base has been set up and final adjustments are in progress. Production of the working standards of mass has commenced in the laboratory workshop.

The programme to supply electronic temperature control equipment for various purposes in the Division has been virtually completed. Eight proportioning controllers, complete with bridges and sensitive elements, and two 2-kVA. transductor units have been built and pleasing results have been obtained from them in operation. In addition a new 0.5-kVA. transductor unit has been designed and is being made.

A continuously variable controller for krypton discharge lamps has been developed. It is entirely mains operated and will control the lamp current over the full range, i.e., 15-80 mA. at 1,500 volts. The experimental controller is in use in the Division and a final design has been prepared from which two controllers are being built. Work has been done on the preliminary design for a 100 Mc/s. generator for mercury 198 discharge lamps.

Officers of the Division took part in the work of various Committees of the Standards Association of Australia, and of the National Association of Testing Authorities, the Engineering Group Conferences of Departmental laboratories, the Engineering Production Convention, and scientific and technical societies. A contribution was made to the Exhibition of Scientific Equipment held in Melbourne.

Relations with industry are becoming closer. The Division has during the past six months been investigating methods of analysing engineering designs for production, the optimum construction of the basic engineering standards in Australia, and the general principles for their most effective application in industry. It is expected that this work will assist the engineering industry to effect improvements in their overall production economy.

In pursuing and stimulating interest in the work, the Division played a leading part in the Engineering Production Convention held to discuss these subjects in the University of Sydney from 21st May to 24th May, 1951. This Convention was sponsored by the Sydney Division of the Institution of Engineers, Australia, and was supported by other professional, industrial, and governmental bodies. Its central theme was twofold: to explore the optimum construction of each basic standard as a national or even international standard, and to consider the best way for each individual firm to establish and use its own local series of standards. Six well-known engineers, including two from the staff of the Division, submitted papers for discussion. Resolutions at the final meeting marked the interest of Australian engineers in the further development of the work. It was recommended that the Council of the Institution of Engineers, Australia, and the Australian Sub-Council of the Institution of Production Engineers jointly establish a co-ordinating committee to continue to stimulate interest in matters relating to engineering production by promoting lectures, conferences, exhibitions, investigations, and like activities.

It is clear that industry now expects the Division to give assistance by taking part in an educational programme on inter-linked fundamentals of production engineering, viz., limits and fits, gauging principles,

screw threads, surface finish, and drawing practice, and by conducting investigation and research in these fields and in the associated practical applications.

2. Length and Associated Quantities.

(*a*) *Universal Comparator.*—The Comparator was installed a short time before the beginning of the year covered by this Report. Since then preliminary trials have been made which indicate that it is capable of giving the high accuracy required in comparisons made with the Commonwealth standards of measurement. Several scales have been measured during the year, including three to be used as standards by the Weights and Measures Department, Victoria. Experience has shown that, in order to attain the accuracy of which the comparator is capable, it is necessary to measure the temperature of the line standard compared to about 0.001° C. It is expected that this will be possible with the platinum resistance thermometers recently made for the comparator by the Division of Physics. A second metre and a second yard standard have been ordered from overseas for use as Commonwealth working standards of measurement.

(*b*) *Dividing Engines.*—A precision linear dividing engine of 40-in. capacity has been installed in a cabinet the temperature of which is controlled by one of the proportioning controllers made in the Division. This engine and the circular dividing engine previously installed have made it possible to make up during the year various scales, micrometer drums, special slide rules, graticules, and surface texture standards. Experience has been gained in ruling very fine lines such as, for example, lines 0.0001 inch wide on unhardened steel and lines 0.0002 inch wide on aluminized glass.

(*c*) *Geodetic Base.*—The component parts of the geodetic base were received from overseas last year, and the installation of the base is now nearing completion. With this installation it will ultimately be possible to calibrate surveying tapes with an accuracy of the order of one part in a million. This accuracy is required for the laying down of base lines for triangulation and for calibrating other tapes such as are used by the various State Lands Departments for the calibration of surveyor's working tapes. All the component parts have been placed in position during the year, and much of the necessary alignment has been done. The next operation is the alignment of the microscopes so that the points on which they are focused lie in the same straight horizontal line to within ½ mm. over the 50 m. length of the base.

(*d*) *End Standards.*—The normal programme for the maintenance of end standards has been continued. Several interesting cases of secular change have been observed, including that of two reference end bars in which there has been not only a change in length and a change in parallelism of the end faces but also a change in the direction of the departure from parallelism.

(*e*) *Measurement of Gears and Examination of Large Gear Hobbing Machines.*—Further measurements were made on the gear of 12-ft. diameter hobbed at an ordnance factory, and one of the mating pinions was also examined. As a result of experience gained during these two previous examinations, several of the large gear measuring instruments have been modified. A preliminary inspection has been made of two other large gear hobbing machines recently installed. The machines are of a different design from those previously examined, requiring new equipment and different methods for some of the tests. The new equipment has been designed and is being made in the Division. Mathematical investigations have been made into the geometrical problems of measurement of gears and gear-cutting hobs.

(*f*) *Air Gauging.*—Three types of air-gauging units have now been installed and used for measurement, experimental work, and demonstration.

(*g*) *Interferometry.*—The development of methods for the standardization of length, angle, and flatness by interferometry has been continued. Associated with this work have been studies in the field of multiple-beam interferometry, and the application of this subject to problems in the structure of metal surfaces and the measurement of vibration.

Work on wavelength standards is still delayed by the difficulty of obtaining from overseas material for the construction of instruments required in this work. Sources of radiation made from the artificially produced isotope mercury 198 have been developed overseas sufficiently in the last year to allow issue of such sources in a practicable form to laboratories concerned with investigations, the ultimate aim of which is the establishment of the wavelength of light as the fundamental unit of length. Such sources of radiation emit wavelengths of almost ideal purity for use as units of length and lamps are being obtained from the United Kingdom and the United States. Work on the wavelengths emitted by these sources will be done in co-operation with overseas standardizing laboratories.

Equipment for the evaporation and sputtering of high reflecting films on glass surfaces was received early in the year and has been used almost continuously for all investigations in interferometry and in the production of graticules for use in the Division. This equipment and the photographic laboratory that was organized as an integral part of the Interferometry Section have been major factors in the successful development of all projects in interferometry.

(i) *Transmission-like Multiple-beam Reflection Interferometry.*—Multiple-beam reflection interference fringes with transmission-like characteristics have some important advantages over normal reflection fringes and have been used with particular success in the work on vibration measurement. A paper is being published on the nature of these fringes, describing the theory of their origin and their experimental production and use.

(ii) *Calibration of Angle Gauges.*—The measurement of angle to a high precision by interferometry has been reported in a published paper. Experimental work has been completed on the calibration of angle standards and on the distortion of the surfaces that occurs when these standards are used. This work will be the subject of a second paper.

(iii) *Wavelength Interferometer.*—Investigations of methods of improving the present routine standardization of length on the wavelength interferometer have resulted in the successful development of a photographic method for recording simultaneously the interference patterns in the red, green, blue, and violet radiations of cadmium. This development allows length determinations to be made with greater reliability and has the additional important advantage of giving a permanent record of all observed interference effects.

(iv) *Kösters Interferometer.*—A modified Kösters Interferometer is awaiting optical glass for prisms for the monochromator and will be used to determine lengths up to 500 mm. by interferometry.

(v) *One-metre Interferometer.*—Material and optics have been ordered for the construction of extensive interferometric equipment whose ultimate purpose will be the determination of the metre in terms of the wavelength of light. The method is based on the use of Fabry-Pérot reflection interference fringes over large distances and considerable work has been done on this aspect of the project.

(vi) *Surface Texture Standards.*—Work has been completed on the absolute calibration of glass surface texture standards by multiple-beam interferometry and a paper has been submitted for publication.

(vii) *Graticules.*—Satisfactory graticules are being produced by the evaporation of pure nickel on to glass surfaces. The method developed earlier within the Division follows a technique which consists of depositing a layer of zinc by evaporation on to a glass surface, cutting lines to the desired pattern through this zinc layer, using a dividing engine, and then depositing by evaporation a layer of nickel over the whole surface. By dissolving the zinc layer clear, sharp, and durable lines of pure nickel are left on the glass surface.

(viii) *Surface Structure and Wringing Studies.*—As mentioned in the previous Report, consideration has been given to the design of equipment for determining the magnitude of normal and tangential forces that act when metal surfaces are in "wringing" contact. Experimental progress has been delayed through lack of staff.

(*h*) *Measurement of Displacement by Capacity.*—Development of an experimental capacitance displacement meter has reached an advanced stage and this equipment has been found to possess high sensitivity and good stability. In order to test the operational characteristics of this equipment experimental capacitive transducers have been built to allow the following measurements to be made: periodic errors in lathes, in which application the error curve is reproduced on the chart of a recorder, the amplitude and frequency of mechanical vibrations, and indenter loads in hardness-testing machines. Encouraging results have been obtained from each of these developments and sufficient work has been done to show that this displacement meter will prove a versatile and useful instrument.

(*i*) *Lapping.*—A tentative theory has been developed of the process of charging a lapping plate and of the functioning of a lap. The experimental testing of the theory requires the use of a very accurately graded abrasive material and an elutriator has been designed which should give adequate resolution of particle diameters in the size range 2-20 microns.

The lapping of thin specimens of material has always presented serious difficulties due to buckling of material as a result of the release of strain in the surface of the specimen. The conditions necessary to prevent buckling of thin specimens during lapping have been investigated and a successful lapping technique has been developed. As a trial this technique was applied to the production of two batches of slip gauges of nominal size 0.01 and 0.02 inch. The result was very successful and yielded slip gauges of the highest quality in respect of flatness and parallelism of the measuring faces. An interesting feature of the technique is that the entire operation, including the final finishing, is performed by machine.

In the preparation of flat lapped surfaces for use in interferometric work one of the difficulties encountered is the elimination of a small number of relatively coarse scratches which are present on lapped steel surfaces. These scratches appear on lapped steel surfaces despite the utmost care in the preparation of the laps, and whatever abrasive is used. It has been found that the scratching is due in some cases at least to the presence of hard particles in the lapping plate itself. This was shown conclusively by the fact that a freshly turned uncharged brass plate scratched the surface of a piece of hardened steel when the surfaces were rubbed together. Experiments are now being made with the object of obtaining lapping plates which are completely free from abrasive material and some improvement has been obtained in the quality of the surfaces obtained on steel from experimental lapping plates.

(*j*) *Photogrammetry.*—The number of requests for calibration of aerial survey cameras and associated equipment is increasing and fixed equipment for this work has been designed and will be built as soon as possible. The provision of this equipment will also make possible the investigation of several problems which have arisen in the course of camera calibration.

(*k*) *Machine Tools.*—A comparatively large number of lathes has been examined during the year for the Department of Customs and assistance has been given to several industrial organizations in the setting up and alignment of lathes and other machine tools. Work has been done on the development of a speedy method for determining errors in lead screws of machine tools.

(*l*) *Calibration and Consultative Services.*—The calibration and consultative services to industry have been maintained during the year as set out below:—

(i) Items tested have included sets of slip gauges, end bars, and other working standards of industry, limit gauges, measuring instruments and equipment, samples of surface finish, and a variety of other items ranging from surveyors' levelling staves to components of scent sprays.

(ii) Advice has been given to industry on equipment and techniques of measurement and on the setting up of standards rooms.

(iii) A pamphlet has been prepared describing the types of tests available at the National Standards Laboratory and fees charged for gauge testing and calibration of measuring apparatus.

(iv) Six laboratories have been inspected by an officer of the Division as one of two assessors for the Metrology Registration Advisory Committee of the National Association of Testing Authorities.

(v) Three courses in metrology are being given by an officer of the Division at the Sydney Technical College.

3. Mass and Volume.

(*a*) *Verification of Standards of Mass.*—The reverification of the laboratory metric standards of mass which was commenced in May, 1950, has been completed. The results show that since the previous intercomparison in 1948 the values of all the more important standards have remained constant to within two parts in 10,000,000. A satisfactory feature of the results was the high degree of stability exhibited by four experimental weights made in the laboratory in 1947 from 25/20 stainless steel. The changes in the values of any of these weights in three years amounts to less than three parts in 10,000,000. An interesting feature of the results is the behaviour of five weights made from nickel chromium alloy. Two of these weights which were received in 1944 have shown irregular changes in mass up to six parts in 10,000,000 during the six years they have been in use. The remaining three weights, which were received in 1948, have shown no significant change in mass in two years. The standards of mass of the State of Victoria were reverified during the year.

(*b*) *Manufacture of Standards of Mass.*—The manufacture has been commenced of the standards of mass required to fulfil statutory obligations. The machining operations for the metric series have been completed and equipment for adjusting the weights is in process of manufacture.

(*c*) *Balances.*—In the course of the intercomparison of the standards of mass it was found that the readings of two of the balances were varying in an erratic manner which prevented the attainment of the required degree of accuracy in the comparisons. The cause of this trouble was traced in each case to the stirrup bearing planes, which had distorted in their mounts and departed from true flatness by about 2 microns. The planes were reset in their mounts so that they were flat to within 0.5 micron. In each case the performance of the balance was improved sufficiently to permit the comparisons to be made to the required degree of accuracy.

This finding shows the need for bearing surfaces of the highest quality in balances used for precise analytical work, particularly in microbalances which are used for the measurement of very small differences in mass with relatively large tare weights.

(*d*) *Capacity Standards and Measurement of Volume.*—The standards of capacity of the State of Victoria were calibrated during the year.

(*e*) *Calibration and Consultative Service.*—The quantity of test work has shown a slight increase over the previous year. Items submitted for calibration included laboratory weights, balances, volumetric glassware of the more standard type, special volumetric apparatus, hydrometers, barometers, and altitude recorders. Advice has been given to outside organizations on the production of high-grade weights, adjustment of balances, and design of special volume-measuring equipment.

4. Watch Rating.

The non-delivery of overseas equipment has prevented much progress during the past year. Advice has been received that the National Physical Laboratory is no longer using the Kew A tests on precision watches and provision is being made in the Division to test watches along the lines recommended by the International Commission for the Co-ordination of the Work of Chronometric Observatories.

5. Applied Mechanics.

An important continuous function has been fulfilled in the examination and verification of materials testing machines and instruments used in the engineering and allied industries. Improvement in the facilities for this work has continued, particularly in the design and construction of equipment for the precise measurement of force, pressure, angular speed, strain, and hardness.

In order to meet the demand for assistance in the solution of problems in vibration isolation, which usually involve the measurement of small vibratory disturbances, attention has been given to the general problem of the isolation of sensitive apparatus from the effects of vibration. Special vibrometers are being developed for the measurement of very small vibrations.

(*a*) *Verification of Materials Testing Machines and Equipment for Industry.*—Materials testing machines and equipment have been examined in test houses at the main industrial centres in New South Wales and Queensland on behalf of the Services Inspection Authorities or at the request of private firms. A significant increase in this class of work has been due to laboratories seeking registration with the National Association of Testing Authorities, on whose behalf the equipment of several laboratories has been examined. Instruments received for examination from private firms, government departments, and the services have included pressure gauges and pressure-gauge testers, tachometers, portable hardness-testing instruments, rubber durometers, diamond indenters, and test blocks for hardness-testing machines.

(*b*) *Development of Facilities for Determining Derived Quantities.*—(i) *Force.*—The proving rings used for the calibration of testing machines must be calibrated to a suitably high order of accuracy. Negotiations are still proceeding for the construction and installation of a 50-ton dead-weight testing machine especially designed for this class of work. A proving ring of conventional design for a capacity of 5,000 lb. has been constructed in the Division.

(ii) *Pressure.*—In the piston type of pressure-gauge tester at present generally in use, the accuracy of calibration is limited by the ability to determine the bore of the cylinder. This bore in high-pressure testers may be as small as $\frac{1}{8}$ inch in diameter and several inches deep and is not readily accessible for measurement. A piston type of pressure-gauge tester especially arranged to facilitate the cylinder bore determination has been designed and constructed and is receiving final adjustments. The installation of apparatus for the calibration of low pressure and vacuum gauges in the range $\pm$ 30 inches mercury has been commenced.

(iii) *Angular Speed.*—Apparatus for the calibration of tachometers, which has been under development for some years, has been modified and installed as a unit of permanent equipment. A paper describing the stroboscopic techniques and the tachometer calibrator has been prepared for publication.

(iv) *Stress and Strain.*—Wire resistance strain gauges have been found useful in certain devices for force-measurement. The calibrating apparatus for these gauges has been modified in design to give improved accuracy. Investigation of some problems requiring stress analysis will be assisted by model tests using the techniques of photoelasticity. Apparatus designed by the Aeronautical Research Laboratories and constructed conjointly with the Division has been installed on concrete foundations and is now being adjusted. Certain optical components are awaited.

(v) *Hardness.*—It is common practice in industry to check the behaviour of hardness-testing machines by the use of test blocks of known hardness. Such blocks must be checked on a machine whose performance is known to a high accuracy. The construction of such a machine has been commenced. It will be capable of making indentation hardness tests by dead load, and will become the reference machine for all hardness testing within its capacity.

(vi) *Verification of Hardness-testing Machines.*—To verify a hardness-testing machine it is necessary to examine geometrical factors such as indenter shape, depth of penetration, &c., and also to determine the true value of the force applied to the indenter. Attention has been given to two methods of verifying *in situ* the depth-indicating element of a Rockwell hardness-testing machine, one method employing a vibrating reed and slip gauges, the other involving the use of an optical comparator. Further work has been done on the development of methods for measuring the indenter load. A miniature proving ring, one inch in diameter, employing wire resistance strain gauges has been designed and constructed and is now being calibrated. An indenter-load measuring device employing the electrical-capacitance-change method of detection has been designed and a first experimental unit constructed. Preliminary tests show the method to be very promising.

(*c*) *Vibration and Noise.*—Two methods capable of determining vibratory movements of the order of one-millionth of an inch are being investigated. This is part of a broader investigation of the problem of the isolation of very sensitive measuring apparatus from the effects of small vibrations, such as occur in buildings. One method employs interferometric technique, the other depends upon electrical-capacitance-change. The interferometric method offers an

attractive means for the absolute calibration of sensitive vibrometers. Two experimental capacitance-type vibrometers have been designed and constructed, one for detection of vertical, the other for horizontal vibration. Both units are undergoing trials. The extent of earth-borne vibration due to traffic, machinery, &c., is an important factor in the study of vibration isolation. The horizontal unit has been used in preliminary measurements of earth-borne vibration in the field outside the laboratory, the overall magnification on a film record of the waveform being about 1,000,000. Further work has been done on the National Standards Laboratory electromagnetic vibration pick-ups.

In the early part of 1951 an urgent request was received for assistance in determining the characteristics of a defect which was thought to be in the gearing of the main turbo-blowers of two new boilers installed in one of the Sydney generating stations. This assistance was sought so that reliable information could be forwarded to the overseas manufacturer of the equipment. It involved tracing the causes of severe noise vibrations and the measurement of their frequency. The predominant noise vibration was traced to the blades of the blower fan.

This noise analysis and another in response to a request from private industry were carried out with improvised equipment, and while successful in these instances, the method employed would not necessarily be satisfactory in other cases. As a result of experience gained, consideration has been given to the preliminary design of an instrument to enable the frequency and amplitude of noise vibrations to be measured and it is hoped to carry out some experimental work on this project in the near future.

(*d*) *Information and Assistance to Industry and Other Organizations.*—Information has been given on such subjects as the measurement of stresses in the columns of an hydraulic press, the design of pressure gauge testers, the measurement of horse-power, angular speed, and hardness, vibration measurement, and isolation and specifications for hardness testing, verification of testing machines, and the verification of proving devices. Assistance has been given to industry in cases such as the following:—

(i) Load-elongation tests on samples of filament wire for incandescent lamps.
(ii) Strain in a pressure vessel under hydraulic load.
(iii) Detecting motion in muscle tissue.
(iv) Vibration frequency measurements in a gear pump.
(v) Amplitude and frequency of vibrations of a wing section.

XXIV. PHYSICS.

1. General.

Division of Physics.—The Division of Physics, one of the three Divisions which constitute the National Standards Laboratory, maintains the Commonwealth standards of measurement of heat and light and associated quantities, and the primary electrical standards. It is engaged also in research designed to improve the accuracy of the methods of maintenance of standards, and to increase the accuracy of measurement, and in research of a more fundamental nature such as the determination of properties of materials at extremely low temperatures and the study of the physical processes associated with the emission of radiation from the Sun.

During the past year much assistance has been given to industry and to other Divisions of the Organization on special problems, particularly in photometry, optics, pyrometry, and heat. Examples of scientific apparatus designed and constructed in the Laboratory to meet special problems in industry or in scientific research were shown at an exhibition of physical apparatus held in the University of Melbourne in February, 1951.

Officers of the Division have taken a prominent part in the work of the Advisory Committees of the National Association of Testing Authorities and in the work of the International Commission on Illumination. An officer of the Division will lead the Australian delegation at the Twelfth General Conference of this Commission, which will be held in Stockholm in June-July 1951, and another member of the Division represents Australia on a committee appointed by the International Organization for Standardization to consider standards in thermometry.

With the establishment of sections of the Organization in Sydney, Melbourne, and Geelong for research on wool and textiles, the work in the Division on the physical properties of wool fibres was brought to a close. The basic equipment constructed for these investigations is being transferred to other laboratories of the Organization.

2. Heat.

As in previous years, much of the work of this Section is the maintenance of the standards for which it is responsible and the calibration of instruments and equipment in terms of these standards. Most important of the standards is that of temperature, and further improvements have been made in the facilities for the maintenance of the International Temperature Scale and the methods of calibration. The Section is in close contact with many industrial and scientific groups and advice and assistance are given in the solution of problems in temperature measurement, heat transfer, viscosity, humidity measurement, and similar fields.

Besides the maintenance of standards and the associated work of testing and calibration, the Division is engaged in a number of fields of research of a more fundamental nature which are described below.

The work of the Division of Physics on precipitation is described in Chapter XXVII., Section 8 (*d*).

(*a*) *Measurement and Control of Temperature.*—The range of temperatures which can be measured in the Laboratory extends from a few degrees above absolute zero (—273° C.) to over 2,300° C. For the greater part of this range temperatures are expressed in terms of the International Temperature Scale of 1948, a scale adopted by international agreement and designed to provide an unambiguous, convenient, and accurately reproducible means of measuring temperatures. Below —183° C. temperatures are expressed in the thermodynamic scale, on which the International Scale is itself based.

The International Temperature Scale was recently revised and the Laboratory has now completed the changes made necessary by the adoption of the new scale. At the same time improvements are being made to the facilities for the establishment and maintenance of both the thermodynamic and International scales and for the calibration of temperature-measuring equipment in terms of these, with the purpose of further improving the ease and accuracy with which measurements can be made. Such improvements include work in all three of the temperature intervals into which the International Scale may be divided, for which the measuring techniques prescribed are with resistance thermometers, thermocouple pyrometers, and optical pyrometers. Gas and vapour pressure thermometers are used for temperature measurements below —183° C.

The most commonly used device for temperature measurement in industry is the thermocouple, which may give rise to erroneous results due to inhomogeneities of either a chemical or a physical nature

in the wires comprising it. Considerable progress has been made in an experimental investigation of the causes of these effects and their correlation with the electrical properties of solids.

As in previous years, many calls have been made on the services of the Laboratory for the calibration of equipment for the measurement or control of temperature, the checking of industrial pyrometric installations, and the rendering of assistance on special problems in the field of temperature measurement. Problems on which advice or assistance has been rendered include the measurement of temperature in brick kilns and in a rapidly moving gas stream, techniques for the calibration of thermocouples and thermometers and for the measurement of the freezing point of milk, precise temperature control at both high and low temperatures, and the measurement of the errors of thermocouples due to lead conduction.

A course of training in temperature measurement given during the year proved very popular with persons concerned with this work in industry and will, it is hoped, help materially to improve the standard of pyrometry in industry.

(*b*) *Hygrometry and Phase Nucleation of Water.*—Although the problem of explaining the mechanism of the formation of water drops from clean vapour was solved some years ago, the similar problem of the initiation of freezing in supercooled water drops is still outstanding. This aspect of phase nucleation is of especial importance in meteorology, and experiments on the supercooling and freezing of water under carefully controlled conditions are in progress.

The Laboratory has, during the year, been called on to do little work in the field of humidity measurement and control, although advice on humidity problems has frequently been given. A special proportioning valve with which it will be possible to establish relative humidities in steps of 5 per cent. from 0 to 100 per cent. in a moving air stream has been designed and constructed. Attention is being given to the development of an automatic dew point hygrometer, similar to one which has been used successfully in the Laboratory for several years, but with a very much shorter time constant. Such an instrument would be of considerable value for the measurement and recording of rapidly varying humidities.

(*c*) *Heat Transfer.*—Although routine measurements of the thermal conductivities of materials are not undertaken by the Laboratory, considerable experience has accumulated on heat transfer problems and equipment for thermal conductivity measurements has been designed and constructed. One such apparatus, a 12-in. guarded plate type, has now been transferred to the Division of Building Research for measurements on insulating materials, and arrangements have been made to lend a smaller, similar apparatus to the Geophysical Department of the National University for measurements on the thermal conductivities of rocks. Some of the substances for which advice on the measurement of heat transfer coefficients has been sought during the year have been steam pipe lagging (*in situ*), high temperature refractories, the human cheek, and wool fleeces.

(*d*) *Precipitation.*—Studies associated with the work of the Division of Radiophysics on the processes of the natural formation and the artificial production of precipitation have been continued. The work on natural rain formation has comprised measurements of the temperatures of freezing of water droplets of various sizes, and of the collision cross-section of water drops to mist droplets relative to which they are moving. Artificial precipitation studies have included measurements on ice crystal formation in clouds of supercooled water droplets by local cooling and by inoculation with various substances. A more detailed account of the investigations is given in Chapter XXVII., Section 8 (*d*).

(*e*) *Low-temperature Physics, Experimental Research.*—Temperatures of the order of 20° K. (−253° C.) have been attained with the cryostat and liquefier which have been constructed in the Laboratory as the basic equipment for this project, but the efficiency of the plant at this temperature was not sufficient to make effective the third or final stage of refrigeration in the unit, with the aid of which the temperature necessary for the liquefaction of helium will be attained. Modifications to improve this efficiency will shortly be tested.

Concurrently with the work on the main cryostat and liquefier, preparations have been made for the research for which the plant will be used. The initial investigations will be concerned with measurements of thermal and electrical conductivities and specific heats. It is proposed to give early attention to tests of conclusions drawn from theories in the field of electrical and thermal conduction developed in the Section. Cryostats for use in connexion with the measurements with which it is hoped to test conclusions from these theories have been constructed and are at present being set up with their associated measuring equipment.

For the detection of gas leaks the mass spectrometer leak-detector has now been made into a self-contained, transportable unit. A controlled leak which has a helium leak rate of 10^{-8} cc/sec. has been constructed for the routine checking of the sensitivity of the unit. At full sensitivity the unit will just react to the helium which is present in the atmosphere to the extent of 4 parts in a million.

The experience of the group in vacuum work in general is now such that its advice has frequently been sought by other bodies on vacuum problems and numerous requests have been received for details of special equipment designed by the Section.

(*f*) *Low-temperature Physics, Theoretical Research.*—In recent years considerable progress has been made in extending the quantum mechanical theory of atomic processes to explain the properties of matter in the solid and liquid states. Particularly important from the point of view of physical theory are the properties of solids at very low temperatures.

(i) *Electrical Conductivity.*—It has been found that the usual theory of electrical conductivity is not valid at extremely low temperatures and an alternative theory has been advanced which explains an anomaly in the conductivity of some metals at very low temperatures.

It had previously been thought that in consequence of a conservation theorem in the theory of solids there should be a marked deviation of the electrical conductivity from the ordinary theory below 50° K. This effect is known to be absent. It has been possible to show by a more detailed theoretical investigation made in the Division that these deviations should be small and should occur only in a small temperature interval at about 10° K.

(ii) *Thermal Conductivity of Semi-conductors.*—Some progress has been made in extending the theory of the thermal conduction of insulators to include semi-conductors, that is, to those solids with properties intermediate between metals and insulators.

3. Light.

The work on the Light Section is in three main fields: photometry, optics, and solar physics.

(*a*) *Photometry.*—(i) *Tests and Calibrations.*—The bulk of the test and calibration work for industry carried out in the Light Section has been photometric

and has been much greater in amount than in previous years. The Laboratory's facilities for the standardization of photometers have been widely drawn upon by Government and industrial laboratories, and many hospitals and pathologists throughout Australia and New Zealand have taken advantage of the Laboratory's arrangements for the calibration of haemoglobinometers in the Laboratory or the despatch by air of blood samples standardized for haemoglobin content and suitable for the calibration of haemoglobinometers. In all branches of photometry there has been a continuous demand for the Laboratory's services.

(ii) *Photometric Standards.*—Investigations have been made on the defects in incandescent lamps for use as photometric standards, and discussions are proceeding with the manufacturers with a view to the removal of some of the defects.

The accurate calibration of fluorescent lamps is beset with difficulty owing to their shape and their spectral characteristics and work is in progress to establish a group of substandard fluorescent lamps measured in terms of the candela. The measurements will be made with the photoelectric photometer developed in the Section and described in last year's Report. The spectral response of this instrument has now been adjusted so that it agrees closely with the visual characteristics of the standard observer adopted by the International Commission on Illumination.

(iii) *Spectrophotometry.*—Because of the need to assess light in terms of the spectral luminosity of radiation, spectrophotometry is basic to a photometric laboratory. To establish a sound foundation for this work, a precision spectrophotometer of high transmission is being constructed in the Laboratory's workshops. This is being fitted with polarization photometers, plans for which are well advanced. Plans are also under way for improving the accuracy of the General Electric recording spectrophotometer and fitting it with means for the absolute calibration of its scale, and for adapting it to the recording of spectral energy distributions of light sources.

To extend the Division's facilities beyond the visual spectral range, a Beckman spectrophotometer is now being used in the ultra-violet range down to 2000Å. For measurements in the infra-red the Perkin Elmer infra-red spectrophotometer of the Division of Food Preservation, which will be used in the Section, will be available.

(iv) *Short-period Transients.*—In order to investigate certain problems of a fundamental nature concerning radiation processes, it is necessary to be able to measure intensity changes in phenomena which last for times of the order of 10^{-8} sec. Electronic equipment is being constructed for this purpose.

(*b*) *Optics.*—(i) *Reflecting Microscopes.*—There has been continued interest here and elsewhere in the development of reflecting microscope objectives, both because of their applicability over wide spectral ranges and because of their long working distance.

The Division has concentrated on developing objectives using spherical surfaces, and during the past year has introduced for ultraviolet use objectives incorporating non-refracting fused-quartz immersion lenses, the effect of which is to increase the resolving power by 50 per cent. The supply of fused quartz of optical quality is acutely short, however, and has been sufficient for only two pairs of condenser and objective. Non-immersion objectives of N.A. 0.72, focal length 5 mm., and central obstruction ratio 0.44 have been developed specially for use in infra-red microspectrophotometry, while an objective of N.A. 0.45, focal length 0.89 in., central obstruction ratio 0.42, and of long working distance 1.78 in., is being made for observation of metal surfaces at high temperature.

These objectives all incorporate two concentric spherical reflectors. While still retaining this concentric condition and thus having a wide field of view, the central obstruction can be reduced to a harmless amount by introducing a third spherical mirror, and an objective based on this principle is at present being made, having N.A. 0.88, focal length 5 mm., and central obstruction ratio 0.33.

An ultraviolet microspectrometer incorporating a fused-quartz immersion-lens reflecting objective has been designed for the McMaster Animal Health Laboratory. It has been constructed partly by the Division and partly by the Organization's central workshops, and is at present in the process of assembly and adjustment.

(ii) *Optical Properties of Thin Metallic Films.*—Investigations of the reflection and transmission of light by thin metallic films and the associated colour effects have been made, taking multiple reflections into account. The study will include the question of the phase change of the reflected and transmitted beams and the results should apply to any form of electromagnetic radiation incident normally on an isotropic absorbing lamina. Experiments to verify the theoretical calculations are proceeding both by photometric and by multiple-beam interference methods.

(*c*) *Solar Physics.*—The work of the Division on solar physics is described in Chapter XXVIII., Section 4.

4. Electrical Standards.

The basic electrical standards of voltage and resistance are maintained by the Laboratory by means of standard cells and resistances which are compared from time to time with the corresponding standards maintained at the National Physical Laboratory of Great Britain. Sets of both cells and resistances have been recalibrated in this way during the year. Frequent intercomparisons are necessary since both cells and resistances change with time. An analysis has been made of the methods of inter-comparison and of the procedures for deriving the accuracy with which the values of the standards are known.

XXV. ELECTROTECHNOLOGY.

1. General.

The electrical research of the Organization is undertaken within its Division of Electrotechnology. The Organization is also collaborating with the Electricity Supply Association of Australia in encouraging electrical research within the Universities through its Electrical Research Board.

The Division of Electrotechnology, which forms part of the National Standards Laboratory, is responsible for maintaining the Commonwealth standards of measurement of electrical units other than the primary standards—the volt and the ohm. In addition to its research on electrical measurements and standards, the Division is investigating the properties of dielectric materials.

The work of the Division during the past year is outlined in Sections 2-7 below. The activities of the Electrical Research Board form the subject of Section 8.

Members of the staff of the Division have continued to serve on advisory and technical committees of both the National Association of Testing Authorities and the Standards Association of Australia. Also, technical advice on both electrical and chemical problems has been given to many inquirers from industry.

The demand for calibration and measurements from industrial and other laboratories of Universities, Government organizations, and public utilities has continued to grow. During the past year the Division issued 122 test reports, an increase of 83 per cent. over the number issued the previous year.

2. Direct Current.

Owing to increased demands for tests the staff of the direct current section have been engaged almost completely on maintaining standards and calibrating measuring equipment. However, some work has been done to obtain a more detailed knowledge of the short-term stability of the Division's standard resistors.

An improved technique has been developed for applying corrections to a decade Wheatstone bridge used for resistance measurements. This technique has advantages when the bridge is used for calibrating resistance boxes. A Kelvin double bridge has been modified to increase the accuracy of measuring the resistance of shunts. The bridge method used at the Bureau of Standards, United States of America, for calibrating potentiometers has been tried with satisfactory results.

3. Power Frequency.

The facilities for measurements at power frequencies have been extended considerably by the development of new equipment and techniques which make it more convenient to carry out tests.

The installation of equipment for controlling the frequency and voltage of the sine wave alternator set is nearing completion. Equipment has been set up in permanent form for calibrating ammeters, voltmeters, wattmeters, and watthour meters using the sine wave alternator set and either the electrostatic voltmeter or the dynamometer wattmeter. For use in calibrating watthour meters, a timing unit has been built which closes an electrical circuit for any preset time interval between 1 and 10,000 seconds. The duration of the interval is controlled by pulses from a crystal oscillator and is accurate to a few thousandths of a second.

To meet the increasing demand for tests on instrument transformers, auxiliary equipment has been developed to reduce the time and labour involved. It includes equipment for demagnetizing transformers prior to test, switching arrangements for supply transformers, and apparatus for reading directly the ratio errors and phase angles of voltage transformers. Also, circuits have been set up to simulate transformers with adjustable errors so that transformer testing sets may be calibrated throughout their ratio and phase angle ranges.

For use in the capacitance divider of the voltage transformer testing equipment, a three-terminal air capacitor of 5 pF. capacitance has been constructed. Experience gained in the development of this capacitor has been applied to the design and construction of a number of capacitors for more general purposes.

An investigation has been made of the properties of transformers when used as inductive ratio arms of bridges at power and audio frequencies. It has been found that it is possible to obtain transformers of high stability with ratios very nearly identical with the turns ratios and with phase angles very nearly zero. Transformers of this type have been used successfully in a number of measuring circuits.

4. Audio and Radio Frequency.

(*a*) *Impedance Measurement.*—The measurement of capacitance and, to a lesser extent, inductance, is the major demand on this Section. The Laboratory's standard capacitors, which are measured by reference to the standards of resistance and frequency, have proved very stable. Considerable progress has been made in simplifying the methods of measurement by the use of multi-ratio transformers as ratio devices in alternating current bridge circuits, and this work is being continued.

(*b*) *Dielectric Measurements.* — Facilities for measurement of the dielectric properties of materials have been extended by the construction of apparatus covering the range of frequencies from 10 kc/s. to 100 Mc/s. A cylindrical resonator has been constructed which will permit measurements at 9,000 Mc/s. to be made at temperatures other than room temperature.

(*c*) *Power Measurement.*—A thermistor bridge for low-level power measurements at radio frequencies up to 300 Mc/s. has been constructed and used to measure the power output of a number of high-frequency signal generators.

(*d*) *Frequency Measurement.*—Although the operation of the frequency standard has been very satisfactory, the installation is being continually modified to simplify its maintenance. The existing crystal oven temperature control, which operates from 50 c/s., requires a standby supply during any failure of the mains power supply. An improved oven temperature control circuit operating from the battery supply has been tested and will be used in the construction of two additional crystal oscillators.

Further progress has been made in the design and assembly of equipment to permit precise frequency measurements to be made in the microwave range with reference to the standards used at lower freqnencies.

(*e*) *Noise Generators.*—Investigations of random noise generators at 3,000 Mc/s. for use in the absolute determination of the sensitivity of radio receivers have been continued. A discharge lamp containing mercury vapour in argon has been compared, as a noise generator, with a low-temperature black-body radiator of known output. The results agreed with those obtained overseas. Larger discharge lamps filled with spectroscopically pure argon are being made in order to obtain a better performance.

(*f*) *Microwave Spectroscopy.*—The sensitivity of the microwave spectroscope has been improved by the development of a square-wave modulation system for the klystron oscillator. The equipment is being redesigned for building into a permanent rack-mounted installation.

The investigation of spectral absorption lines in nitrosyl chloride which had been undertaken has been postponed temporarily because workers overseas have carried out measurements on this compound. A study of carbonyl chloride (phosgene) is being undertaken in its place.

5. Magnetic Measurements.

A new type of magnetometer has been developed in which the field-sensitive element is a fine mu-metal wire. This instrument is of great value in permeameter measurements and for measuring steady fields of intensities up to 40 oersteds and in modified form for measuring higher field strengths. The original instrument is operated from the mains power supply, but additional equipment for battery operation is being constructed to permit magnetic testing to be carried out when necessary at locations remote from interfering "man-made" fields.

6. Dielectric Investigations.

Investigations have been continued on the dielectric properties of materials in an endeavour to relate their molecular and crystal structure with their dielectric

loss. Most of the work has been done with long-chain polar derivatives of hydrocarbons and, in particular, with the alcohols. Considerable attention has been given to the preparation of pure samples of these materials, since it was discovered that their dielectric properties at low frequencies are extremely sensitive to impurities.

Apart from long-chain compounds, measurements are also being made on a cyclic compound, hydroquinone, which is of interest because of its crystal structure.

(*a*) *Theoretical Investigations.*—Calculations concerning the dielectric absorption of substances containing straight chains of hydrogen-bonded dipoles or movable imperfections in ionic lattices have been completed. The main result of these investigations has been to show that for each chain the dielectric loss as a function of frequency is practically indistinguishable from a Debye curve. This confirms the previous conclusion that the much wider absorption range exhibited by solid long-chain alcohols is due to a large spread in the lengths of the chains of hydroxyl groups.

In the course of the calculations a number of computational techniques were evolved which are generally useful in numerical work.

(*b*) *Dielectric After-effect.*—This effect in capacitors, which is also known as charge "soaking", is characterized by an anomalous charging current which continues after the normal charging current has ceased. The study of this effect has been continued during the year, using mixtures of small quantities of liquid alcohols with either paraffin wax, docosane, or polytetrafluoroethylene ("Fluon"). The effects of varying temperature, concentration of alcohol, thickness of specimen, and applied voltage gradient have been investigated, and the electrical measurements have been extended to 50,000 c/s. It has been found possible to interpret the charging current measured with applied D.C. as an extension to low frequencies of the loss factors measured on A.C. The work carried out so far has thrown considerable light on the mechanism of the after-effect, but it has not yet been possible to develop a quantitative theory.

(*c*) *Dielectric Properties of Hydroxy Compounds.*—Previous measurements at low frequencies with *n*-primary alcohols were carried out chiefly on compounds of chain length greater than 16 carbon atoms. The compounds of shorter chain length were found to give variable results and were set aside for further investigations at a later date. The work on these compounds is now being continued, particular attention being paid to their purity and to the technique and conditions of measurement.

The investigation of the abnormally large dielectric absorption of secondary alcohols at audio and radio frequencies has been extended to include measurements at different temperatures in an effort to find out more about the details of the mechanism involved. Dielectric cells suitable for this work have been constructed. Measurements are being made with both the form obtained by solidification from the melt and the form obtained by recrystallization from a solvent. The effects of heat treatment are being investigated.

In addition to the long-chain hydroxy compounds, measurements are being made on the dihydric phenol, hydroquinone. According to the structure indicated by the X-ray crystallographic data for this compound it should give no dielectric absorption, but the results of preliminary electrical measurements show a high dielectric absorption. This may be explained by a temporary modification of the structure caused by the grinding process used in preparing the material for measurements. These investigations are being continued.

(*d*) *Dielectric Properties of Long-chain Fatty Acids.*—The crystal structure of fatty acids is such that, although the individual molecules are polar, the dipole moments of adjacent pairs of molecules cancel. Consequently there should be very low dielectric loss in this type of compound. This has been confirmed by measurements carried out between frequencies of 1 c/s. and 10^4 Mc/s.

(*e*) *Measurements for Industry.*—A chemical manufacturing company has been advised concerning the suitability of dielectric measurements for detecting certain critical concentrations in mixtures of two liquids. Some measurements were carried out and it was found that for one of the mixtures the method was useful and could be applied in production.

The dielectric properties of some chlorinated aromatic compounds and of some specimens of mica sheet were measured in response to requests.

7. Vacuum Electronics.

Improvements have been made to the scale-of-ten counter tube which was developed last year. Requests from organizations interested in the possibility of producing the counters on a commercial basis have been met by sending detailed information and a working counter tube overseas. Further details of this work are given in Chapter XXX., Section 3 (*d*).

8. Electrical Research Board.

The Electrical Research Board is representative of the Electricity Supply Association of Australia, the Universities, and the Organization. Its general objective is the fostering of fundamental electrical research in Universities. Since its inception in 1945, the Board has been developing its programme along two main lines: the study of the economics and stability of interconnected power systems, and automatic control and communications. Investigations on the first of these subjects have been established, with the support of the Board, in the Universities of Adelaide, Melbourne, and Tasmania. Studies in automatic control and communications have been undertaken in the past in the University of Sydney and are being taken up again in collaboration with the Organization's Mathematical Instruments Section. In the University of Sydney work has been continued on the high-voltage direct-current generation of power, the study of arcs, and electromagnetic waves. Work on the protection of electrical plant from lightning has been initiated in the University of Queensland.

XXVI. RADIOPHYSICS.

1. General.

Investigations relating to the propagation, transmission, and detection of radio waves and to the application of radio techniques to problems in other fields are carried out by the Division of Radiophysics and by the Radio Research Board.

Division of Radiophysics.—The main laboratories of the Division of Radiophysics are in the grounds of the University of Sydney. The work of the Division has been continued and extended along the lines described in last year's Annual Report. The main investigations in progress at the present time are as follows:

(i) A scientific study of the way in which rain and cloud occur naturally, of the possibility of inducing rain by artificial means, and of the effectiveness of various methods of rain-making. During the past year the potential importance to Australia of non-freezing rain has been established. Non-freezing rain does not originate in ice crystals and hence the well-known dry ice and silver iodide methods are not effective in

inducing it. Theories of the development of this type of rain have been worked out and a possible method of stimulating it artificially is being investigated.

An analysis of the successes obtained with dry ice now makes it possible to specify not only the type of cloud with which this method is likely to be effective but also to assess, at least for areas in the vicinity of Sydney, the sort of meteorological conditions under which such cloud forms are likely to occur.

The Division's work on rain and clouds is described in Chapter XXVII., Sections 8-10.

(ii) A comprehensive study of the radio waves which reach the Earth from sources outside it, i.e. from the Sun, the Galaxy, and that special class of bodies known as radio stars. This is the new province of radio astronomy. The Organization's contribution to this new science has been a significant one and it is largely in recognition of this that the International Scientific Radio Union has agreed to hold its next General Assembly in Australia in 1952. Research in radio astronomy is reported in Chapter XXVIII.

(iii) A very large amount of research concerning the ionosphere is being carried out both in Australia and in other countries, utilizing pulses of radio waves which are reflected from the ionosphere. An attempt is being made to develop other means of observation. These investigations are described in Section 2 below.

(iv) The application of radar techniques to the provision of improved radio aids to navigation is described in Section 3 below. During the period under review, several fully engineered models of a microwave navigation system have been completed for full-scale trials under commercial flying conditions.

(v) High-speed aids to scientific computing. Extensive use has been made of the methods already developed for using standard accounting type punched-card equipment, and during the past year substantial progress has been made towards the completion of a modern high-speed electronic digital computer entirely designed and built within the Division. This work is described in Chapter XXX., Section 3 (*b*) and (*e*).

Radio Research Board.—The Board's investigations are concerned particularly with conditions in the atmosphere which affect radio propagation.

The full-time staff of the Radio Research Board is located in the Electrical Engineering Department of the University of Sydney and at the Commonwealth Observatory on Mount Stromlo, Canberra. In addition, the Board assists approved projects at the Universities of Adelaide, Queensland, Tasmania, and Western Australia. It is also co-operating with the Australian National Antarctic Research Expedition in radio observations at Macquarie Island, and is assisting that Expedition in the planning of its programme.

The Board's officers have taken an active part in the work of the International Scientific Radio Union and presented papers to the meeting at Zurich in 1950. The Board's Chief Scientific Officer led the Australian delegation to Zurich, where he was elected a Vice-President of the Union and re-elected President of its Commission on Radio Astronomy.

Two members of the Board and one of its officers also visited the United States of America by invitation as scientific consultants to the United States Army Air Force.

Recognition of the value of the Board's work came from the Royal Society of New South Wales, which awarded its Walter Burfitt medal for 1949-50 to the Chief Scientific Officer for "outstanding researches in the ionosphere".

The Australian Radio Propagation Committee continues to serve as a technical advisory committee to the Board and as a group for discussion of practical applications of radio propagation information. Its members include representatives of the Services and of Government organizations concerned with radio propagation. Its interests are mainly in the field of ionosphere propagation, but it is also examining the problems of troposphere propagation of the very high frequency radio waves, particularly as regards their use for short-distance radio telephone links.

Information now available enables useful working predictions to be made of the general conditions which control radio propagation in the upper atmosphere, but there are many regular and irregular effects on which more information is required. The Board's investigations have continued along lines previously indicated, and have added materially to our knowledge of these. They are described in Sections 4 and 5 of this Chapter.

2. The Ionosphere.

The investigations concerning the ionosphere carried out by this Division are aimed broadly at developing new techniques for the study of the ionosphere. Some have their origins in radio astronomy.

This is evident in a series of observations of the attenuation suffered by waves from the Galaxy on a wavelength of 15 m. as they pass through the ionosphere. Attenuation due to two causes is being studied. Firstly, at times of occurrence of solar flares it is known that on short wavelengths long-distance radio signals frequently disappear. The effect is known as a "fade-out" and is believed to be due to absorption in that part of the ionosphere, at a height of about 75 km., which is known as the D-region. A similar effect is observed on the cosmic radio waves during "fade-outs". Secondly, the cosmic radio waves show a decrease when the critical frequency of the F_2-region, the uppermost reflecting region in the ionosphere, exceeds about half the frequency of the radio wave. The feature of these observations is that the rays must pass right through the ionosphere, so that their behaviour can supply information about the upper parts beyond the point where signals used in communication are reflected back to Earth.

In addition to causing general absorption the ionosphere also gives rise to fluctuations in the radiation received from the radio stars, "radio twinkling". Observations of this effect have been carried out and lead to the conclusion that the irregularities in the F-region of the ionosphere are a major cause. A more extensive series of observations is being analysed.

A contrasting series of observations concerns the measurement of the temperature of the D-layer of the ionosphere by means of the radio-frequency radiation emitted thermally by it at a frequency of 2 Mc/s. This method is precisely analogous (using radio waves) to the measurement of the temperature of a furnace by means of an optical pyrometer (using light). It was, however, derived directly from a similar technique applied at a different radio frequency to measure the temperature of the atmosphere of the Sun. There is difficulty in finding situations where interference from such causes as lightning flashes and electrical machinery is sufficiently small, but it has been shown that the method can be successfully applied during the middle of the day at places far removed from electrical machinery and a series of observations at a remote place in the country near Bourke, extending over a year, is nearing completion.

The region responsible for this emission (the D-region at a height of about 70 km.) is not readily investigated by the usual pulse methods of ionospheric research, and observations are in progress using very long waves from the naval transmitter VHP at Canberra (wavelength 6.8 km.). Similar research, mainly on rather longer wavelengths, has been actively pursued at Cambridge, England, and it is desirable to extend such observations to Australian conditions. The lower parts of the ionosphere from which these very long waves are reflected are chiefly responsible

for attenuation of the shorter ones. At the time of fade-outs the increase in attenuation on short wavelengths mentioned earlier is known in England to be accompanied by a reduction of height of the reflecting region for long waves by up to 10 or 20 km. The Australian observations agree with the English ones in this respect but the polarization and the diurnal height variations present new features.

In addition to actual observations on the ionosphere, a theoretical examination has been made of the mode of formation of the layers of which it is composed. This suggests, among other things, that the rate of decay, and hence the amount of radiation necessary to maintain the ionosphere, is substantially greater than has been supposed. This is related to a suggestion that the ionization of part of the ionosphere may be caused by soft X-rays emitted by the Sun.

3. Radio Aids to Navigation.

In recent years one of the most important "applied" activities of the Division has been the development of improved navigational aids which are likely to have particular application to conditions existing in Australia. Two major radio aids for civil aviation which have emerged—Distance Measuring Equipment and a Multiple Track Range or guidance system—have been described in previous reports. The Department of Civil Aviation is now taking delivery from the manufacturer of beacons and airborne units as part of the Commonwealth-wide installation of D.M.E. equipment which has been planned, and the Division's responsibilities, so far as short-range D.M.E. is concerned, are now complete except for duties of a general advisory nature. Some interest in M.T.R. continues to be shown both in Great Britain and in Australia, and further advice and technical information on the performance of this system have been given. The main activities of the navigation group during the past twelve months have been devoted to the engineering development of a microwave navigational system and to preliminary work on the possibility of using distance measuring techniques to provide a long-range navigational system.

(*a*) *Microwave Navigational System.*—The Division's Microwave Navigation System was designed to provide a radio counterpart to the simple visual method of navigation. It provides facilities for "seeing" and using radio beacons as nearly as possible in the same way as ground markers or light signals may be identified and used as navigational aids under conditions of perfect visibility. It has aroused considerable interest both in Australia and abroad as a navigational system for use by aircraft under conditions where it is uneconomic to provide the more elaborate facilities which are usual on main air routes, and also for use in the navigation of ships in confined waters.

Extensive tests carried out last year with experimental equipment showed the performance of the airborne version to be promising. During the period under review the system has been fully engineered, and six ground beacons and six airborne units have reached an advanced stage. They will be handed over to the Department of Civil Aviation for trials under commercial flying conditions. The ground station or beacon is a simple low-cost unit which can be installed at short notice wherever power is available. The successful development of battery-operated beacons would provide a valuable aid for outback air routes or for use in parts of New Guinea, and work along these lines is proceeding.

To assess the possibilities of the system for harbour pilotage and navigation in confined areas, trials are being made in conjunction with the Maritime Services Board. A receiver has been installed in the pilot ship of Sydney Harbour and appropriate beacon installations are being laid down.

(*b*) *Long-range Navigation using D.M.E. Techniques.*—D.M.E. in its present form is a short-range aid, since it operates at a wavelength of about 1½ metres where reliable propagation beyond the line of sight cannot be achieved. The extension of the technique to ranges up to 1,000 miles would represent a major advance in long-range navigation. Methods in use at present all suffer from the disadvantage of requiring a fully trained navigator to obtain a position fix. D.M.E., however, for the short ranges on which it is at present used, gives the pilot a direct indication of range which is both automatic and continuous. Its use over long distances would involve propagation via the ionosphere and research is therefore being carried out into various aspects of communication via the ionosphere which are likely to have a bearing on the feasibility of such a system.

4. The Effects on the Upper Atmosphere of Particle Radiations from the Sun.

Earlier theories to explain the effects in the earth's atmosphere of particle radiation from the sun have not been completely satisfactory. An exhaustive theoretical study by the Radio Research Board's officers has, however, produced a revised theory which appears capable of explaining how the solar radiation may produce the actual effects observed on the earth, such as interference with radio propagation, magnetic disturbances, and auroral displays. This theory has been discussed at conferences in America, Europe, and Australia, and has aroused world-wide interest. A preliminary report has been published. Disturbances of the ionosphere with a characteristic daily variation have also been discovered.

5. Travelling Disturbances.

The observations of travelling disturbances in the ionosphere have been continued and extended. The change from summer to winter of daytime directions of movement has been clearly established, and it now appears that there is a systematic change of direction during the day. This is thought to be the result of tides in the atmosphere. It has also been shown that the direction of movement is generally not the same at 100 km. as at 250 km. height. Work at Brisbane has given evidence of similar movements at night. The observations at Perth are obtaining evidence of the directions of movements in Western Australia, thus providing information on the extent of the movements.

A paper on this work has been published and further papers have been read at conferences in America, Europe, and Australia.

Observations of a similar nature are now being undertaken in other parts of the world. In Australia the work is being continued and extended as it is giving valuable new information on movements in the upper atmosphere, which are of importance in meteorology and high-altitude flight as well as in radio propagation.

XXVII. METEOROLOGICAL PHYSICS.

1. General.

Research into physical phenomena occurring in the atmosphere is carried out by the Section of Meteorological Physics located at Highett, Victoria, the Division of Radiophysics, Sydney, and the Division of Physics, Sydney.

Work on the physics of rain and clouds and on artificial production of rain by the Division of Radiophysics, and laboratory investigations of precipitation by the Division of Physics, are described in Sections 8-10 of this Chapter. Investigations by the Division of Radiophysics into wind and other phenomena in the upper atmosphere are reported in Section 11.

Statistical studies of rainfall made by the Section of Mathematical Statistics, Adelaide, are reported in Sections 12 and 13.

Section of Meteorological Physics.—The Section of Meteorological Physics was formed mainly for the purpose of making fundamental studies in the physics of atmospheric processes. The field of investigation thus presented is wide, including studies of conditions all over the world in the problems of changes occurring from day to day (synoptic meteorology), week to week (weather trends), or decade to decade (climatic trends). On an intermediate scale exist problems such as the mechanics and structure of individual storms, cloud, rain, fog, &c.; and from this the scope ranges down to the study of the detailed structure of temperature, humidity, and wind near the surface of the ground, which, besides exerting a profound influence on the properties of the atmosphere as a whole, determines the nature of the climate in and around crops, and hence the welfare of plant industries.

The work of the Section during the past year has been largely consolidation and extension of work described in previous reports. It is described in Sections 2-7 of this Chapter. The Section is not immediately concerned with the problem of weather forecasting, but it is generally conceded that any substantial progress in the accuracy and extension of time of forecasting is contingent on success in such basic studies as those in which the Section is engaged. Likewise, the efficiency of such weather controls as are at present contemplated, such as fog dispersal, frost prevention, and the formation of artificial rain, must rely on fundamental knowledge concerning the mechanism of these various processes.

2. General Circulation.

The central problem in the general circulation of the atmosphere is the elucidation of the manner in which heat is transferred from equatorial to polar regions in order to maintain the heat balance of the earth as a whole. The nature of such transfer is largely responsible for seasonal weather. During the year under review the Section of Meteorological Physics has continued the analysis and interpretation of world-wide upper air data.

Important progress has been made in the study of momentum exchange between the latitudes by the completion of a world survey of the stress between atmosphere and oceans.

3. Dynamic Meteorology.

The manner in which solar energy is transformed into the kinetic energy of atmospheric motions, and the general working of the atmospheric heat engine, are among those meteorological mechanisms still not completely understood. Studies in these problems have been maintained during the past year, and are continuing.

There is, in synoptic meteorology, a need for a systematic characterization of pressure systems, so that one may be distinguished from another in terms of appropriate parameters. Studies recently undertaken in the Section indicate that it may be possible to introduce some such classification based on the vertical rate of decay of the horizontal pressure gradient of the individual system.

4. Micrometeorology.

Micrometeorology is that branch of the subject concerned with the detailed structure of wind, temperature, humidity, &c., and the behaviour of these elements in the layer of air just above the ground.

All these elements reveal a highly complex structure, and the effects of this structure have a profound influence on a wide range of superficially unlike phenomena such as the warming of the atmosphere near the earth's surface, the evaporation of water from land and sea, the transport of the lighter seeds, the dispersal of smoke from factory areas, &c. Indeed, it may be said that life as we know it is largely shaped by the turbulent processes that occur in the lowest layers of the atmosphere. Thus the study of the processes occurring in these regions is of fundamental importance from the purely meteorological point of view, as they control the transfer of solar into atmospheric heat energy, and also from the commercial and agricultural aspects.

The work on these problems carried out in the Section has been largely of a fundamental nature. It has been concerned with the development of apparatus suitable for recording the fine structure of the elements under study and with the extended use of the apparatus in the field. This experimental work has been mainly carried out at the Section's experimental station at Edithvale, where completion of the 96-ft. observation tower and extension of the observation hut have greatly facilitated the work. The observational programme, now well under way, is believed to be in some ways unique, including measurement of all the factors concerned in the heat balance at the earth's surface and also of the frictional force between the atmosphere and the ground. This latter, the turbulent transfer of heat and water vapour, and the transfer of heat into the ground, are all measured by means of instruments developed in the Section, and analysis of the results is yielding important information on the laws of turbulent transfer in the lower atmosphere. Up to the present the investigation has been concerned mainly with clear weather, but will soon be extended to other conditions.

The instrumental technique used for measuring the turbulent transfers of heat and water vapour (i.e. evaporation) is capable of application to any natural surface and, in particular, to conditions over growing crops. It is believed to be the first method for measuring natural evaporation which is entirely free from objections in principle, and it is hoped that it may later find application in agricultural research in Australia, where an understanding of evaporation is of pressing concern. It must be stressed, however, that the method is at present complicated instrumentally and requires a trained physicist to operate it.

The Section participated in a summer cruise of R.R.S. *Discovery II.* to the Southern Ocean. Measurements were made of sea surface temperature in the convergence zone, of the fine structure of air temperature, and of wind over the sea surface, the latter for the purpose of evaluating the frictional force between atmosphere and ocean. This quantity, of which exact knowledge is scanty, is of great importance in the study of the general circulation.

5. Frost Prevention in Orchards.

In practically all Australian fruit-growing districts frost occurs only in a shallow layer close to the ground. The air at 50-100 feet above the ground may be some 10° F. warmer on such occasions, and may therefore be used as a source of heat to prevent frost damage to the fruit trees. To tap this source, various types of fan have been used both in Australia and overseas, but as no systematic investigation appears to have been

made for the purpose of determining the most efficient system, the work of the Section in this field has been directed to this end.

The trials, which have again been carried out at Griffith, have continued along lines indicated in the previous Report. They have confirmed that tilting the axis of the fan, so that the air is given some horizontal momentum, leads to a significant increase in its efficiency, the area influenced being about 50 per cent. greater at an angle of tilt of 60°, compared with the vertical downdraught. Preparations have been completed for extending the trials during the coming winter so that the effect of rotating the projected air stream around the orchard every one to three minutes may be examined. It is considered that such rotation should lead to a considerable increase in efficiency.

Fruit-growers in the Tocumwal district have had installed a rotating ducted fan which, during the coming winter, will be subjected to quantitative test. The thermometric equipment necessary for this is similar to that used at Griffith and has been constructed and installed by this Section, which will be largely responsible for the observational work in connexion with this investigation.

6. Radio Meteorology.

The structure of the troposphere and of that layer of the atmosphere known as the ionosphere is due ultimately to solar influence. It might, therefore, be expected that there would be some relationship between the behaviour of the two though, because of the quite different physical nature of this influence, this relationship could not be expected to be close. Correlations have been sought between ionospheric critical frequency and such tropospheric parameters as tropopause height, pressure, &c. Significant correlations of small magnitude have been found for certain periods, but do not appear to be maintained. The investigation is continuing.

An undertaking of considerable economic importance to Australia is the establishment of radiotelephone links between the capital cities. The efficiency of such links is profoundly influenced by the meteorological conditions in the lower atmosphere, and the need for an investigation into such influence is fully realized by the Postmaster-General's Department. The Section is continuing to advise the Department on the meteorological aspects of the problem.

7. Evaporation Survey.

Surveys of evaporation over the Australian continent are an essential guide in problems of land use and rural development. Previous surveys of this kind have been based on measurements from evaporation tanks. Such measurements, while providing useful information in certain directions, are recognized as being limited in application, and more realistic methods are required. To this end specially developed evaporation pots have been or are being installed at certain stations in south-eastern Australia, namely at Griffith, Merbein, Adelaide, and Highett.

8. Rain Physics.

A clear picture of the mechanisms involved in the production of natural rain, besides being of considerable scientific interest in its own right, is an essential prerequisite to any successful methods of inducing rain artificially. Radar offers unique advantages for studying the processes at work within rain-bearing clouds because of its ability to "see" the snow or raindrops throughout the whole extent of the cloud. It has been used extensively by the Division of Radiophysics in various forms during the past year. The data collected confirm previous findings that, in addition to freezing rain (rain which commences its life as ice crystals), there is another very important natural method of rain formation, in which the initial ice crystal stage is not involved. The process is one of collision and coalescence of small drops to form big ones. Non-freezing rain is almost certainly an important source of rainfall in tropical and sub-tropical latitudes.

(*a*) *Airborne Observations of Rain Clouds.*—Radar observations are made from a specially equipped aircraft fitted with a 10-cm. radar set. This combination has proved invaluable because it makes possible a survey of clouds within a range of 200 miles or more. The radar provides a reliable means of finding the clouds which contain raindrops and of following the development and decay of the rain-bearing regions within them. At the same time the use of an aircraft makes it possible to examine the actual particles which are giving rise to the radar echoes by flying through the clouds concerned. Sufficient observations have now been made to establish that the radar "bright band", which is always associated with freezing or "Bergeron"-type rain, is produced when ice crystals become covered with a thin film of water as they fall to or pass below freezing level in the atmosphere. For this reason it has been proposed that in future it should be called the "melting band". Other radar observations have shown that rain often occurs within clouds which are not cold enough to contain ice crystals and visual observations from the aircraft have confirmed that the source of the radar echoes is water droplets and not ice crystals.

(*b*) *Ground Radar Observations of Rain.*—The use of ground radars is necessarily confined to the study of clouds which happen to pass in their near vicinity. Nevertheless, because the radar site itself is fixed, it is possible to make a better statistical study of the incidence of various types of cloud than is feasible from an aircraft and, in individual cases, to follow the development in greater detail. During the year a vertical-looking radar, which is installed on the roof of the Laboratory and thus provides data on vertical sections through cloud areas in the vicinity of the Laboratory, has been fitted with a camera which photographs the radar screen at frequent intervals. Such a series of pictures provides a permanent record of all stages in the development of rain areas and, when projected at normal film speed, gives a graphic representation. It has been found in this way, for example, that with freezing rain (i.e. when a melting band is present), other radar bands sometimes form at greater heights. These usually fall slowly and merge with the melting band, after which the process may be repeated at regular intervals. The occurrence of these upper bands appears to be due to spontaneous freezing of water droplets within the cloud itself when they fall to a temperature of about −16° C.

(*c*) *Raindrop Sonde.*—While aircraft measurements are invaluable in providing the horizontal structure of drop sizes, they do not readily yield information on vertical structure or on variations with time at any one level. For this purpose a balloon-borne instrument is employed, consisting essentially of a microphone connected to a radio transmitter. Raindrops strike the diaphragm of the microphone and modulate the carrier wave according to their momentum, and from the audible tone produced in a receiver on the ground, the size of the drops and their number can be determined. This method, though valuable, is necessarily restricted to occasions when reasonably uniform rain conditions are present in the vicinity of the ground recording stations.

(*d*) *Rain Formation.*—Investigations on certain processes of particular interest in connexion with the artificial and natural production of rain have been

continued in the Division of Physics. Further laboratory measurements have been made of the number and types of ice crystals produced in a fog of supercooled water droplets when it is locally cooled by a pellet of carbon dioxide snow (—78° C.). To complete this investigation similar measurements using materials other than CO_2 and at temperatures other than —78° C. are being made.

Similar measurements on the ice crystals produced by silver iodide have been made. It has been found that free iodine vapour and the products obtained by heating potassium iodide are also effective in producing nucleation, particularly at low temperatures. The techniques and facilities developed for these measurements have proved useful for examining silver iodide smokes and pyrotechnic mixtures containing silver iodide for their suitability for field trials for artificial rain production. Different mixtures have proved quite different in their effectiveness in producing ice crystals.

The temperature at which water droplets freeze has been reported by overseas workers to depend on the size of the drop. Investigations have confirmed in a general way that the freezing temperature of small drops is lower than that of larger drops, although much greater variability in the results was obtained than has been reported by some workers, presumably because of the considerable difference in the experimental techniques used. An investigation of a somewhat similar nature but under much more carefully controlled conditions and directed towards a different end, that of the study of phase nucleation in very pure water, is in progress in the Division and is reported in Chapter XXIV., Section 2 (*b*).

The capture cross-section of raindrops for finer drops relative to which they are falling is obviously an important parameter for theories of rain growth in which coalescence is assumed to be important. Calculations of its value under various conditions have been made but all such calculations involve simplifying assumptions, and it therefore seems desirable for an attempt to be made to measure the quantity directly. The first attempts to do this, in which the mist droplets were made to carry a tracer, the concentration of which was measured in the water of the large drops after they had fallen through the mist, did not provide results of sufficient accuracy. The alternative approach of measuring the rate of growth of a drop of pure water suspended in a rising air stream containing droplets of pure water and of a velocity near the terminal velocity of the large drop, proved more satisfactory and has the advantage of avoiding the use of a contaminated spray. The results obtained to date do not differ greatly from some of the theoretical values but the experiments need to be extended over a wider range of conditions. In the course of the investigation a new method of determining the spectrum of sizes of the mist droplets has been developed.

Non-freezing rain is common in tropical and subtropical latitudes but the way in which it forms (unlike that from icy clouds) is very little understood. A theory which accounts for the production of large drops initially by condensation and then by a much more rapid growth due to coalescence has been further developed in the Division of Radiophysics and checked with experimental observations. Some further theoretical work has also been completed on the relationship between rain and the existence of condensation nuclei. This suggests that clouds formed in maritime air masses should tend to contain much larger drops than those formed in air masses which have passed over land and these conclusions appear, so far, to be supported by actual observation.

(*e*) *Laboratory Experiments on Reflection from Water Drops and Ice Particles.*—The features of the radar echoes obtained from clouds depend on the way in which the scattering of radio waves by water droplets differs from that due to ice crystals in their various possible forms. Measurements have been made in the Radiophysics Laboratory to verify the theoretical calculations of the proportion of energy scattered by water drops and ice particles. These show that the well-known radar "bright" or "melting" band can be adequately explained as due to the increased reflection from crystals which have just begun to melt. As an ice needle melts, it becomes covered with a film of water which enhances its scattering power. This is reduced again as the crystal collapses to a spherical drop.

(*f*) *Raindrop Spectrograph.*—In interpreting the results obtained by the use of ground radar and the raindrop sonde, it is desirable to know the distribution of the sizes of raindrops which actually reach ground level. An instrument has been developed which is particularly effective for this purpose. The raindrops are allowed to fall through a small hole in the top of a horizontal wind tunnel. As they fall into the horizontally-moving windstream they are carried along a distance which is an inverse function of their size and deposited on the base of the tunnel, where a sheet of paper is placed. The paper is dusted with a red water-soluble dye so that red stains are left where the raindrops fall. The paper is arranged to move across the wind tunnel and a record is thus obtained which shows the distribution of raindrop sizes at any instant, and also how distribution varies with time.

9. Artificial Rain Formation.

In parallel with the studies of natural rain described above, the effects produced by treating natural clouds with various substances are being investigated by the Division of Radiophysics.

(*a*) *Dry Ice.*—Dry ice was the first substance to be used successfully in rainmaking experiments. It is effective only in supercooled clouds whose tops are at least 7° colder than freezing. The Division's earlier work led to the first published specification of the cloud conditions under which artificial rainmaking by the dry-ice method is likely to be successful, and to the realization that careful measurement and recording of physical conditions during such experiments are essential to a full understanding of the process. Owing to the excessively high rainfall in the Sydney area during the period under review, favorable opportunities for the use of this method occurred relatively rarely. The opportunity has, therefore, been taken to improve the instruments and instrumental techniques employed.

An investigation has been made of the meteorological conditions which existed on those days on which successful rain-making experiments were carried out in the Sydney area between January, 1948, and June, 1950. They had many recognizable features in common and as a result, provided adequate radio-sonde and synoptic data are available, it has now become possible to assess whether a given day is likely to be suitable for dry-ice trials. By this means it is estimated that conditions in the Sydney area were favorable on 45 days during 1948, on 33 days in 1949, and on only eight days during the period January to June, 1950. Potential rain clouds appeared often enough in the latter period but they nearly always yielded natural rain.

(*b*) *Trials in Tasmania.*—Following requests from the Tasmanian C.S.I.R.O. State Committee that artificial rainmaking be tried out in that area in view of the serious effects the current drought was having on that State's hydro-electric and forestry services, two visits were made to Tasmania by the Division's rain-making group. The first was for the purpose of carrying out a preliminary survey of the possibilities.

These appeared to be favorable and a full-scale trial of the dry-ice method was carried out over a period of one month in a serious attempt to increase the rainfall over the Hydro-Electric Commission's catchment areas. During the second visit natural conditions proved less favorable and only two constructive experiments were carried out. The evidence collected was insufficient to make possible an assessment of whether rainmaking in this area would be an economic proposition. Valuable experience was gained, however, on the organization which would be required to make rain and to observe and properly assess the results.

(*c*) *Silver Iodide.*—Silver iodide, when introduced into a cloud in the form of a "smoke" of fine crystals, appears to cause effects very similar to those produced by dry ice. It is effective only in supercooled clouds. Spectacular successes have been claimed for it in the United States of America but detailed evidence on which these claims could be assessed has not yet been published.

Opportunities for trials with silver iodide have, as with dry ice, occurred in the vicinity of Sydney on relatively few occasions during the past twelve months. Means for distributing it satisfactorily from an aircraft have been developed, however, and a number of experiments have been carried out. From these all that can be said so far is that rain-making by this method is apparently possible but appears to be more critical of cloud condition than the dry-ice method.

(*d*) *Water Spray.*—According to a theory developed in this Division to account for the occurrence of rain in non-freezing clouds, the large raindrops arise from the occasional appearance of a proportion of larger droplets which fall relative to their smaller neighbours and in the process collide and coalesce with them. This process, repeated many times over, can ultimately result in the droplets growing to raindrop dimensions. These considerations suggested that the introduction of larger droplets into the base of a cloud in which an up-draught existed might stimulate and accelerate the process. Experiments are, therefore, being carried out to check this prediction; if it is verified, then obviously a powerful method of stimulating rain from non-freezing clouds (on which dry ice and silver iodide have no effect) would become available. Difficulties have been met in obtaining and fitting the necessary equipment for releasing adequate quantities of water droplets of appropriate size from an aircraft; in consequence the method has been tried on only eleven occasions. On four of these rain or hail appeared shortly after the spray was released and on six other occasions distinct modification of the cloud form was observed. The method therefore appears promising, but many more trials will be necessary before it is known with certainty whether the effects so far observed were due to the introduction of the water spray. The technical difficulties referred to are being overcome and active experimental work with this method will shortly be resumed.

10. Cloud Physics.

(*a*) *Vertical Air Velocity.*—A knowledge of the vertical flow pattern within convective clouds is particularly relevant to an understanding of their development and of the growth of droplets within them. This has proved difficult to measure. Earlier methods using "window" (a light-reflecting material used during the last war to confuse the enemy's radar) proved unsatisfactory because its natural rate of fall varied as the paper stiffening material became wet within the cloud. The use of very short lengths of fine wire has been tried but the most promising method appears to be the use of light-weight paper spheres coated with aluminium foil. These may be "seen" individually by a radar set and their movement, which is a function of that of the air in which they are floating, plotted.

(*b*) *Cloud Water Content.*—It is important to know how the amount of water in droplet form varies within a cloud and few reliable measurements of this appear to have been made. A special instrument has been designed for this purpose which gives a continuous record on being carried through a cloud in an aircraft. A strip of absorbent paper is exposed and the cloud droplets are collected on it. A change in the electrical resistance of the paper strip takes place and these changes in resistance are recorded. Measurements made on cumulus-type clouds of moderate depth show that the amount of water in the cloud increases gradually from the base of the cloud, reaches a maximum, and then decreases rapidly towards the top. The measurements also show that there are very marked variations in the water content in any horizontal traverse of a cloud.

(*c*) *Cloud Drop Spectra.*—Useful information has been collected on the variations in size and number of the droplets of which typical clouds are composed. These observations are made by a sampling process. A small cylinder coated with magnesium oxide is exposed automatically for a fraction of a second from an aircraft in flight. When a cloud droplet hits this cylinder, it produces a permanent crater in the coating. The size of this crater is proportional to the drop diameter and can be measured at the conclusion of the flight. The results indicate that clouds which form over the sea contain fewer and larger drops than those which have passed over land masses. Such a result could be due to differences in the nuclei on which condensation takes place in the respective air masses and is likely to be a vital factor in the formation of rain.

11. Upper Air Investigation.

(*a*) *Wind Measurements at Great Heights.*—Recent developments in both civil and military aviation make it clear that operational heights of 30,000 feet and greater are likely soon to be in regular use. Little is known of the prevailing winds at and above this altitude, particularly in the Southern Hemisphere. Some previous exploratory work by the Division suggests that the wind pattern is probably similar to that in the Northern Hemisphere, but systematic observations over an extended period will be necessary to establish the upper air wind data with sufficient accuracy for operational use.

The tracking of special reflecting balloons by radar offers an excellent method for evaluating the wind structure at various heights, since such observations can be made to much greater ranges than by visual means and equally reliably under all conditions of weather and visibility. A radar set specially adapted for this purpose has been built on the roof of the Laboratory and regular observations with it are about to commence.

(*b*) *Homing Glider.*—For measurement of meteorological conditions other than wind velocity and direction at great heights, it is necessary to carry appropriate instruments to these heights. Excluding cases in which aircraft are used, most of the present methods make use of small radio transmitters which are carried aloft by hydrogen-filled balloons. In only a very small percentage of cases, however, are the instruments recovered. The Division is developing a radio-controlled glider to be taken up and released at the desired height by the balloon. After release the glider, in its descent, is directed automatically towards a transmitter on the ground and hence is recoverable. During the year two experimental flying-wing-type models of 5-ft. span and capable of carrying a pay

load (e.g. of meteorological instruments) of 12 lb. have been completed and flown under manual radio control. Development of automatic homing gear for installation in these models is well advanced. In this project considerable assistance on aerodynamic problems has been given by the Aeronautics Department of the University of Sydney and, on the use of veneers for the construction of the flying models, by the New South Wales Forestry Commission.

12. Expectation of Monthly Rainfall in South Australia.

The decision to increase the scope of this investigation was mentioned in last year's Report, and during the period now under review all calculations for the agricultural areas in South Australia were completed and work on data from the pastoral regions begun. For the agricultural areas the results include the probabilities that the season will open and terminate in specified months, and also the probabilities that the season during which the rainfall in successive months will exceed the amounts required to balance average potential evapo-transpiration, will be of specified length.

13. The Determination of Rainfall Isohyets.

The development of climatology in Australia during recent years has made it increasingly important to know as accurately as possible the position of rainfall isohyets. An investigation has therefore been initiated with the object of developing a technique for the construction of isohyets, by taking the altitude and position of recording stations into account.

When this work has been completed, it will be possible to determine the precision with which rainfall at any one station can be predicted from values of the same variate at neighbouring stations and, more important still, to determine the density of observing stations required to provide any assigned accuracy to the predicted values.

XXVIII. EXTRATERRESTRIAL PHYSICS.

1. General.

The usual method of observing the Sun or the Moon or the myriads of other astronomical bodies is by means of the light they emit. It is now possible to make similar observations by means of radio waves, and the Division of Radiophysics has taken an important part in the development of this new science. Observations have been made of the radio waves emitted by the Sun, the Moon, and the Milky Way, and these observations are contributing important new facts to our knowledge of the Universe.

The work of the past year falls into two divisions, relating to the Sun and to the universe beyond the solar system, and is described in Sections 2 and 3 of this Chapter.

The Division of Physics has continued its investigations on visible and ultraviolet radiation from the Sun, and these are reported in Section 4.

Work by the Radio Research Board on the effects on the upper atmosphere of particle radiation from the Sun is described in Chapter XXVI, Section 4.

2. Radio Waves from the Sun (Solar Noise).

Systematic measurements of the intensity of radio waves from the Sun have been continued on wavelengths of 3, 10, 25, 50, 300, and 500 centimetres and some measurements made on 17 metres. Observations of the position on the solar disk of "radio" disturbances and of the polarization of waves from them on a wavelength of 3 metres have continued. Equipment for two new series of measurements is being constructed. The first will give the spectrum of solar disturbances over the wavelength range 1.2-10 metres in order to provide an extension of the observations taken last year over the range 2.3-4 metres. The second equipment will have a sufficiently narrow beam to pick out small active areas on the solar disk. It will operate at a wavelength of 25 centimetres. These areas, which are distinct from those observed on the 3-metre equipment, were observed during two eclipses visible in Australia in recent years, but it is clearly desirable to be able to observe the changes in them which occur from day to day instead of being restricted to the rare occasions on which eclipses of the Sun occur.

The most important new observation during the year was that the base level of radiation, which is due to thermal emission from the hot gases of the solar atmosphere, fell markedly in the decimetre range of wavelengths as the sunspot maximum receded. This must be due to a major change in the solar atmosphere.

With regard to the various forms of disturbance recorded, observations have mainly substantial hypotheses reached last year. On decimetre wavelengths it appears probable that the slowly varying component is due to thermal radiation from localized regions in the solar atmosphere of gas at a temperature of perhaps 10,000,000° C. The 25-centimetre equipment under construction is designed to locate these. On longer wavelengths the prolonged disturbances known as "noise storms" have been shown to originate very high in the corona. Their existence depends on the presence of an exceptionally large sunspot, and the sense of rotation of the polarization of the radiation emitted (which normally is circularly polarized) depends on the magnetic polarity of the spot concerned. Thus it seems probable that the "noise storm" is due to the penetration of the magnetic field of a sunspot to a sufficiently high level in the corona, but the mechanism of the generation of the radio waves is not known.

The intense but short-lived disturbances known as "outbursts", which are associated with solar flares, now appear to be almost certainly associated with the ejection from the Sun of those clouds of particles which travel to the Earth and, on their arrival, cause terrestrial auroras and magnetic storms. The source of the radiation is seen to move rapidly across the disk of the Sun at the time of ejection of particles. If this hypothesis is accepted, the radio waves can now be utilized to study the emission of these particles. This was not previously possible because they do not appear to emit visible light.

3. Cosmic Radio Waves (Cosmic Noise).

Observations of cosmic radio waves have been extended to both longer and shorter wavelengths than those previously used and a survey of the "radio stars", using a wavelength of 3 metres, has been completed. On the relatively long wavelength of 15 metres a survey of the distribution of cosmic noise over a zone of the sky has been completed and a number of radio stars in this zone observed. On the short wavelength of 25 centimetres a similar survey was possible in the vicinity of the galactic centre only because of the very low intensity of radiation at this wavelength. A number of radio stars and an object of a diffuse nature were observed.

The waves are obstructed to some extent on their way to us. The radio stars show fluctuations similar to the familiar twinkling of visible stars and, on the longer wavelengths, definite absorption effects are sometimes noticed. Some or all of these latter effects appear to be due to the terrestrial ionosphere and are mentioned in Chapter XXVI., Section 2.

The most direct evidence on the nature of radio stars would be from the identification of these with visible stars. Out of about 100 known radio stars there are only three which have been even provisionally identified. A further attempt to locate the very bright radio star in the constellation of Cygnus sufficiently accurately to identify it with an optical one again failed. The location fell in a uniform field of thousands of stars with no outstanding object in the vicinity.

Another method of getting information about the radio stars is through a statistical study of their distribution in direction. The brightest visible stars, which, broadly, tend to be the closer ones, are distributed at random, while the fainter ones are concentrated towards the plane of the Milky Way. Present evidence, which is limited by the fact that the number of known radio stars is unduly small for statistical purposes, suggests that the bright radio stars, unlike the bright visible ones, are concentrated near the plane of the Milky Way.

If we assume that all the cosmic radio waves are due to the integrated effects of radio stars, it is possible, on certain further assumptions, to estimate the number of radio stars and the power emitted by each. Such an analysis has been made and leads to the conclusion that the number is probably very great but not so great as that of the optical stars.

Turning to the question of the shape of the Galaxy, radio evidence was presented last year to show that our Galaxy is a spiral. The observations have been further examined and an estimate has been made of the distribution of radio sources, which probably broadly follows that of the stars, in the central regions of the Galaxy.

4. Visible and Ultraviolet Radiation from the Sun.

Officers of the Light Section of the Division of Physics engaged in solar physics have concentrated in the past year on theoretical investigations of the processes in the Sun's chromosphere associated with the emission of visible radiation, and the construction of a spectroheliograph for photographic study of details of the Sun's surface.

Extensive calculations have been made of the radiation emitted by a solar atmosphere of pure hydrogen under various conditions of temperature and pressure, chosen as far as possible to agree with physical conditions in the solar chromosphere. The uncertainty in our knowledge of the chromosphere, particularly with respect to its temperature distribution, coupled with the necessary simplifications of the model atmosphere used, makes it difficult to obtain a direct comparison of the calculations with observations. It is possible, however, by considering the hydrogen light observed to be emitted by the Sun in the visible and ultraviolet regions, to put a limit on the temperature of the chromosphere as normally observed. It is hoped that extension of this work to atmospheres composed of other elements present in the chromosphere may help in solving the problem of the temperature distribution there.

Progress in the construction of the mechanical parts of the spectroheliograph has been delayed by other urgent projects in the National Standards Laboratory workshops, and the special filter for isolating a very narrow band of monochromatic radiation, ordered a year ago, is still to be delivered by the manufacturer in France. A simpler filter which will pass a wider spectral band, suitable for the photography of prominences, is being constructed in the laboratory's optics workshop, and electronic equipment has been designed and partly assembled to enable the spectroheliograph to follow the Sun automatically.

In mathematical investigations of the processes occurring in the Sun's chromosphere, it is necessary to consider the motion of electrons in electric and magnetic fields. Arising out of these studies a solution has been found to an interesting theoretical problem concerning the path and energy of a charged particle moving in a magnetic field which varies at a uniform rate.

XXIX. Atomic Physics.

1. General.

The Organization is co-operating with the Physics Department of the University of Melbourne in a programme of research on nuclear physics and cosmic rays under the direction of Professor L. H. Martin.

Co-operative investigations on cosmic rays are also being undertaken at the University of Tasmania under the direction of Professor A. L. McAulay. This work is described in Sections 2, 3, and 4 of this Chapter.

By arrangement with the Commonwealth Department of Health the Tracer Elements Unit has continued to operate in association with the Commonwealth X-ray and Radium Laboratory under the general supervision of the director, Dr. C. E. Eddy.

2. Nuclear Physics.

(*a*) *Disintegration of Light Elements.*—Experiments on the angular distributions of disintegration products from light target nuclei bombarded with deuterons and protons have been continued.

Earlier research reports described experiments on the angular distribution of alpha particles in the Li(7)p.α reaction. Nuclear emulsion plates were used to record the alpha particles, the distribution of which was found to be capable of representation by an expression the form of which indicates the presence of f as well as p protons in the reaction even when the proton energy E was less than 1 MeV.

The experiment has been repeated using scintillation counters to record the alpha particles. The experiment was designed specifically to test the evidence of an unexpected resonance near 400 keV. and to improve the precision of the measurements near 1 MeV. The latter was important since American work extends over a range of proton energies from 1 MeV. to 3 MeV. and the precision at 1 MeV. is rather poor. The variation of $A(E)$ with proton energy has been studied theoretically by Inglis and the exact placing of a maximum in $A(E)$ near 1 MeV. is significant in the evaluation of parameters in the theoretical expression for the angular distribution. A detailed study of $A(E)$ near 400 keV. failed to confirm the evidence of earlier measurements of a resonance at 400 keV.

The angular distribution of the alpha particles in the Li(6)d.α reaction has been measured for deuteron energies between 200 keV. and 1 MeV. The asymmetry is found to be represented by an expression consistent with the increasing penetrability of the centrifugal barrier for d wave deuterons.

In the Li (6)d.p reachtion, two groups of protons are observed, the short-range group being associated with the formtaion of Li(7) in an excited state. The angular distributions of both groups of protons have been measured with nuclear emulsion plates, special development processes being used to differentiate between protons and the alpha particles described above. Pure isotopic targets of Li(6) were produced with the aid of a modified mass spectrometer.

It has been found that the long-range proton group shows the greater complexity in this angular distribution. The form of the distributions favours the assignment of spin $I = \frac{1}{2}$ for the excited state of Li(7).

Preliminary experiments have been made on the angular distribution of tritons and helium (3) nuclei from the interaction of deuterons with deuterium nuclei. An electron-multiplier has been constructed which detects the H(3) and He(3) nuclear particles, from measurements on which it is possible to deduce the

differential yield curves for protons and neutrons in the reactions D(d.p)H(3) and D(d.n)He(3). It is hoped in this way to avoid the difficulty experienced in previous experiments of measuring the intensities of high-speed neutron beams.

(*b*) *Electron Synchrotron.*—The electron synchrotron is now running at approximately 15 MeV. with a maximum output of some 30 g. radium equivalent at a distance of one metre.

A study of the angular distribution of the X-rays produced by the electron beam striking a thin platinum target has been made using small ionization chambers. In an energy range of 10-14 MeV. the results are in good quantitative agreement with the theoretical predictions based on the theories of multiple electron scattering in thin targets and of the polar diagram of bremsstrahlung.

The disintegration of the deuteron into a proton and neutron by X-rays of quantum energy in excess of 2 MeV. is a powerful means of studying problems of the neutron-proton interaction. Preliminary work has been completed in which radiation from the synchrotron is used to disintegrate deuterium contained as a gas target in a Wilson expansion chamber. Special synchronizing apparatus has been developed to operate the synchrotron in conjunction with the cloud chamber, and a statistical study of the range and angular distribution of the ejected protons is made by photographing proton tracks with three cameras.

3. Electrostatic Generator.

The construction of a four-belt electrostatic generator has been completed. The maximum operating voltage is approximately 800 kV. and short circuit charging currents up to 1.25 mA. have been measured. The accelerating tube has been built and a satisfactory focusing electrode system developed for the r.f. source. The beam is analysed with a 90° electromagnet and stabilized.

A study was made of the relation between short circuit charging current and the ambient temperature and humidity. An air-conditioning plant has been installed which maintains optimum conditions, with relative humidity less than 45 per cent. at 60° F.

The generator provides beams of several hundreds of microamperes of protons and deuterons between 100 and 700 kV., intense beams of neutrons, both fast and slow, and gamma rays of quantum energies up to 17 MeV.

At present experiments are proceeding on the Li(7)d.α reactions with a Wilson expansion chamber. In these reactions the compound nucleus Be(9) can break up in alternative modes, He(5) + He(4) or Be(8) + n. The first reaction leads to a continuous distribution in energy of alpha particles, the second to a homogeneous group which derives from Be(8) → 2He (4). Quantitative studies have yet to be made on these alternative reactions.

In the present experiments deuterons are introduced to the expansion chamber through a very thin mica window and bombard a thin lithium target mounted in the centre of the chamber. Alpha particles of the second reaction may be distinguished by their range and the fact that they must occur in oppositely directed pairs.

Other experiments under consideration with this high-intensity generator are the study of the angular distributions of the gamma rays from the excited level of Be(8) with a 10-channel pulse analyser and anthracene scintillation counter; the forward scattering of 3-MeV. neutrons by deuterons; the angular distribution of the light products in the D-D reaction; and the angular distribution of alpha particles from the Li(7) p.α reaction in the range 50-250 keV.

4. Cosmic Rays.

(*a*) *Nuclear Interactions.*—Nuclear emulsions, Ilford G5, 400 microns thick have been carried by balloons to heights of the order of 90,000 feet. These emulsions register the products of the interaction of cosmic-ray particles with atoms of the emulsion.

A statistical study has been made of nuclear disintegrations which appear as stars in the developed emulsion. Stars have been obtained (with as many as 32 prongs) showing the evaporation of the target nucleus by charged and uncharged primary particles with energies greater than 50 BeV. Primary particles have been observed with masses up to 10 proton masses.

Interesting examples have been observed of a new interaction in which a neutral particle (mass approximately 2300 electron masses) decays into a proton and a meson.

Recently an event has been observed in which a neutral particle of energy 20 BeV. interacts with a proton to give three collinear minimum ionization tracks, one of which is identified as a meson. Evidence has been found of electron pairs produced by the materialization of gamma rays which probably had their origin in the decay of neutral mesons produced in the primary event. The analysis of the whole event should be of importance in the theory of meson production which at present is in a state of flux.

(*b*) *Cosmic-ray Spectrometer.*—The investigation of the momentum distribution and positive excess of mesons is being continued with the cosmic-ray spectrometer. The results obtained in the vertical direction are complete and have been published in full. Two interesting features of these results are that the momentum distribution shows a marked increase of slope above a momentum of 10^{10}eV/c., and that the +/− ratio of mesons increases at first with increasing momentum, reaches a maximum at approximately 5×10^9 eV/c., and then appears to decrease slowly for further increase of momentum.

The experiment has been repeated for zenith angles of 30° and 60° to the west and further measurements are in progress at zenith angles to the east.

An experiment has been designed to study the relation between the probable ionization and momentum of high energy charged particles.

A proportional counter filled to a pressure of 86 cm. Hg with a mixture of argon and ethylene has been inserted in the cosmic-ray spectrometer, giving a simultaneous measurement of both the probable ionization and momentum of the cosmic-ray particles.

Preliminary measurements have been made on some 400 particles capable of penetrating 10 cm. of lead and having momenta greater than 2.4×10^8 eV/c. These results indicate that for μ mesons, the probable ionization does not show the theoretically expected increase with energy above the minimum of ionization. Preliminary results have been published.

(*c*) *Short-time Intervals of Cosmic-ray Origin.*—The high-speed spiral time base chronograph which was developed for the measurement of the lifetimes of mesons, and used for this purpose, has now been applied to the study of other short-time intervals of cosmic-ray origin. Using ordinary Geiger counters to detect the passage of the particles, and in spite of the relatively large reaction times of these counters, the time of flight of cosmic-ray mesons over 5.45 metres has been detected. It is $1.9 \pm 0.5 \times 10^{-8}$ sec., which is not significantly different from the 1.8×10^{-8} sec. that would be required at the velocity of light.

It is believed that this is the first direct measurement showing that the penetrating cosmic-ray particles travel with the velocity of light.

When the apparatus was triggered by extensive air showers, and the difference between the time of firing of an unshielded counter tray and one shielded with

10 cm. of lead was recorded, a time lag of $2.1 \pm 0.4 \times 10^{-8}$ sec. was proved to be associated with the shielded tray. The mathematical analysis, as far as it has gone, indicates that this lag can be explained by an internal effect. This means that the vast majority of the particles near the core of an extensive air shower must arrive at the earth's surface within a time interval very much less than 10^{-8} sec.

(*d*) *Structure of Cosmic-ray Showers.*—Air showers of cosmic-ray particles were studied with the aid of two high-pressure ionization chambers together with a horizontal array of Geiger counters, consisting of a "master group" over one chamber and "analysing counters" at different horizontal distances. By observing the rate of discharge of the array in coincidence with bursts of ionization in the chambers, information was obtained about the structure of *extensive* showers. The sharp rise in the coincidence rate of an analysing counter as it was moved towards the master group could be explained only by the existence of *narrow* showers. A similar behaviour of the rate-separation curve of the two ionization chambers confirmed the existence of this phenomenon.

The burst-rate of a single chamber was subdivided into components due to extensive showers, narrow showers, and other agencies. The exponent of the integral distribution in number of bursts of different sizes was found to be 1.5 for extensive showers and 3 for narrow showers. The remaining bursts were assumed to be due to nuclear disintegrations in the chamber wall, small groups of high energy photons and electrons, mesons, and the N component. The burst rate due to nuclear disintegrations was found to agree with that calculated theoretically.

Considerable theoretical analysis of chamber and counter data was carried out, with emphasis on the rate-separation curves and their dependence on the structure function of the shower. A new method of analysis of coincident bursts of ionization was developed which helps to elucidate the structure function.

(*e*) *Absorption of Cosmic Rays in Water.*—An examination of the hard component of cosmic rays is being carried out by measuring their absorption in water. Depths up to 90 feet are available at Melton Reservoir. A three-fold counter telescope measnres the cosmic-ray intensity in a narrow cone about the vertical after the rays have traversed 10 cm. of lead. A fourth counter tray measures the fraction of this radiation which is incapable of traversing a second 10 cm. of lead. This will provide information on the integral and differential range spectrum for the hard component in water.

It is proposed to compare the results obtained with the momentum spectrum as measured directly in this laboratory by the cosmic-ray spectrometer.

(*f*) *Asymmetry at High Latitudes.*—Measurements of the high latitude east-west asymmetry have been continued at the University of Tasmania, Hobart.

5. Tracer Elements Investigations.

The Tracer Elements Unit has continued to provide advice and assistance to Australian users of radioactive isotopes, which find applications in many fields of scientific research. However, shortages of laboratory accommodation and staff have restricted activities and made it necessary to defer several new investigations.

(*a*) *Procurement and Distribution of Isotopes.*—During the year 64 shipments of eleven different radio-isotopes, totalling 1,443 millicuries, including labelled compounds, have been received. The bulk of these have been obtained from the Atomic Energy Research Establishment at Harwell and the Radiochemical Centre at Amersham. However, one shipment was from a United States of America commercial firm, one from the United States of America Atomic Energy Commission, and several were cyclotron-produced materials supplied free of charge by the Department of Terrestrial Magnetism of the Carnegie Institution, Washington.

Of the above, 47 shipments, totalling 1,375 millicuries of radio-phosphorus and radio-iodine, were obtained for the Commonwealth X-ray and Radium Laboratory for distribution for medical research, diagnosis, and treatment. The others were distributed for research purposes to nine Divisions of the C.S.I.R.O., to eleven departments of five Universities, and to the Kolling Research Institute, Sydney, and the Walter and Eliza Hall Institute of Research, Melbourne.

(*b*) *Investigations with Radio-iodine.*—In the use of radio-iodine for diagnosis and treatment, measurements of the iodine in the body and in excretions are required. The Unit has collaborated with the Royal Melbourne Hospital in this work. The relative merit of several methods of assessing thyroid function by radio-iodine is being investigated.

Assistance with radio-iodine investigations of rat tumours and other biochemical problems has also been given to the Department of Biochemistry, University of Melbourne, and a method for handling material for the radiation thyroidectomy of mice has been developed with the Department of Veterinary Physiology, University of Sydney.

(*c*) *Radio-chemical Synthesis and Processing.*—When isotopically-labelled compounds have not been readily available from overseas suppliers, consideration has been given to their synthesis by the Tracer Elements Unit. During the period under review C^{14}-labelled methyl ethyl ketone has been made for the investigation of the Meerwein-Ponndorf reaction by the Department of Chemistry, University of Adelaide. Trial carboxylations of Grignard reagents have been completed, enabling the preparation of acids such as acetic acid and phenylacetic acid labelled in the carboxyl group. Preliminary work is also in progress on the labelling with C^{14} of glycerol, and α-ketoglutaric acid in two positions.

In addition, sources have been prepared on particular types of mountings, or in a particular chemical form, as required by various users.

(*d*) *Pilot and Assay Experiments.*—Pilot tracer experiments and assay measurements have been made with several C.S.I.R.O. Divisions and other organizations. These have included collaboration with the Irrigation Research Station, Griffith, using long-lived radio-sodium, Na^{22}, to follow the movement of salt in the soil, and with the Walter and Eliza Hall Institute of Research in the assay of C^{14}-glycine.

Discussions have also been held with several industrial firms in connexion with tracer applications, and experiments are planned in collaboration with a firm of chemical manufacturers for tracer studies of yields in industrial chemical processes under different conditions of plant operation.

For assay work, primarily of C^{14}-containing samples, wet oxidation methods for the production of barium carbonate are being developed.

The continued strong demand for radio-active assay equipment has been met with the help of the Organization's Central Experimental Workshops. Further batches of cylindrical and end-window types of lead castles of improved design are under construction, and a prototype castle with an annular recess for powder samples is under test.

(*e*) *Information.*—During the year information on available isotopes, equipment, and tracer methods has been supplied in response to inquiries from Australia and overseas research workers. It has included several roneoed reports and some lists of references on application of isotopes to particular problems.

In addition, during August, 1950, a four-day Conference on Applications of Isotopes in Scientific Research was organized jointly by the Department of Chemistry, University of Melbourne, and the Organization. The conference was well attended by representatives from most Australian research groups and from a number of industrial firms.

XXX. MATHEMATICS.

1. General.

The Section of Mathematical Statistics, with headquarters in Adelaide and officers located also in Canberra, Sydney, Melbourne, and Perth, provides skilled mathematical assistance in the planning of experiments and interpretation of results for workers in other Divisions and Sections. The Section also undertakes research projects itself and these are reported in Section 2 of this Chapter, in Chapter VII., Sections 13 (*d*) and 19 (*b*), and in Chapter XXVII., Sections 12 and 13.

The work of the Section of Mathematical Instruments is described in Sections 3 and 4 of this Chapter, and work by the Division of Radiophysics and the Division of Electrotechnology on computing equipment and methods in Section 3.

Further development has taken place during the past year, with the establishment of two additional centres able to provide direct assistance to Divisions in the conduct of their experimental work. Participation in the Organization's activities is still limited by paucity of staff, but there has been considerable improvement in this regard, and the effect should be felt within a year or so. With this stimulus the outlook has become more encouraging, and with the staff now in training for ultimate attachment to various centres the Section can reasonably expect fulfilment of its goal of maximum assistance to the Organization's research programme.

The nature of the work handled for Universities, Federal and State Departments, commercial establishments, and independent research workers has been diverse, and the requests for such assistance many. From time to time, also, the Section is asked to provide lectures on specialized subjects, and these, together with regular courses delivered within University schools of mathematics, serve to promote interest in mathematical statistics and its applications.

Section of Mathematical Instruments.—The Section of Mathematical Instruments is located in the Electrical Engineering Department of the University of Sydney and is concerned with the development and use of automatic calculating machines and automatic control devices. The Section provides facilities for honours students in the Department of Electrical Engineering to work on special projects associated with its programme.

2. Statistical Methods.

(*a*) *Experimental Designs.*—A frequently occurring and important class of experiment is one in which different treatments are applied in succession to the same unit of experimental material, and under these conditions it is necessary to consider the residual effects of preceding treatments on the latest treatment. For example, in crop rotation trials where the object is to determine the succession of treatments over a number of years which will give the best results for the series as a whole, the estimation of the effects of previous treatments is of direct interest whether the criterion is yield, market value, or the maintenance of soil fertility. In other situations, such estimations may be of indirect concern only. Thus in feeding experiments with animals, a series of treatments (rations) may be fed to a group of animals with the primary object of determining which particular ration gives the best results according to some predetermined criterion. The effect of previous treatment would be of indirect interest, and would be estimated only to provide a correction in estimating the effect of the treatment which followed.

It has previously been reported that experimental designs balanced for the residual effects of treatments have been developed. This work has now been extended to designs balanced with respect to the residual effects of pairs of treatments, thus facilitating further the interpretation of the results of such experiments.

(*b*) *Interpretation of Interactions in Factorial Experimentation.*—In factorial experimental designs, the treatments or factors under test are used in all combinations to increase the efficiency and comprehensiveness of experimentation, and to broaden its inductive basis. The results obtained from such experiments provide information on the average effects of each factor and on the manner in which these effects change as the remaining factors are varied. Observations of this type are most easily interpreted when the effects of the several factors are additive, but frequently it is preferable, and much more reasonable, to regard the effects of one factor as proportional at different levels of the remainder rather than constant, for example, in agricultural field trials where the object is to compare the responses of a crop to various rates of application of different nitrogenous fertilizers, or in studying catalysis where the variants are concentration of catalyst and its time of contact with the substrate.

This investigation was undertaken to determine the appropriate manner in which to make the statistical analysis of the results of such experiments.

(*c*) *Exact Tests of Significance in Discriminant Analysis.*—In various types of experimental work, sets of measurements of several characteristics are made on each of a number of individuals belonging to different groups. A problem that very often arises in the analysis of such data is to determine whether a single linear function of the characters that have been measured can be used to discriminate adequately between the groups to which the individuals belong, and to evaluate such a function. For example, a plant pathologist may classify, on the basis of the degree of discoloration of their roots, a number of wheat plants into, say, four classes (slight, medium, severe, and very severe) according to the severity of their infection with the disease known as take-all. To establish the objectivity of a classification of this nature, other characters of the plants known to be influenced by the disease are measured, namely, number of ears per plant, height of plant, weight of 1,000 grains, percentage grain, and yield. The problem is to determine a linear function of these measurements which will best discriminate between the several grades of severity, and to establish that the original classification has resulted in a significant differentiation of the four classes. The statistical analysis used for this purpose is appropriate also for plant or animal selection in breeding programmes, taxonomic problems, and so on.

The work reported here was designed to increase the scope of exact tests of significance in this phase of multivariate analysis.

3. Computing Equipment and Methods.

(*a*) *Analogue Computers.*—The major work of the Section of Mathematical Instruments on analogue computers has been the completion and putting into service of the differential analyser. In February the principal parts of the machine were demonstrated in

Melbourne at the Exhibition of Physical Equipment arranged by the Australian Branch of the Institute of Physics. Since then the machine has been in constant use and much operational experience has been obtained by members of the Section. The problems which the machine has been used to solve include a pondage problem for the Snowy Mountains Hydro-electric Authority, a temperature distribution problem for an industrial concern, and the solution of certain equations governing the sensitivity of a bimetallic disk for the Department of Aeronautical Engineering at the University of Sydney. A number of other problems have been received and these, together with the work already in hand, represent something like a year's programme for the machine.

In addition to this work, a very complete investigation of electro-dynamical integrators was made by a final-year engineering student.

(*b*) *Digital Computers.*—The usual process of carrying out computing work has involved the use of desk computing machines which can carry out an operation, e.g. addition, in a period of the order of a second. Electronic computers, however, can be designed which perform a similar operation in a thousandth of the time. The construction and use of such a machine involves two separate but interlocking series of problems: the design and construction of the machine itself, and the evolution of new lines of approach to computing problems which will make best use of the machine. In these respects help is available from overseas experience, but only in regard to the most general principles. There is not yet any standard form and each variant involves new problems.

A large high-speed electronic computer has been designed by the Division of Radiophysics and the construction nearly completed. The individual units are operating and work is proceeding on the problem of the interconnecting of units so that the machine may carry out assigned programmes. It is hoped that this phase will shortly be completed so that experimental computations may commence.

Work in this field by the Section of Mathematical Instruments has been confined to the investigation of new computing devices. Experimental work is at present proceeding on the development of a bistable multivibrator and gating unit having its elements enclosed in one envelope. The principle of operation of this unit depends on the deflection of the electron beam into various stable positions. A magnetic memory unit of considerable capacity is being constructed. Work on the electrostatic storage unit is proceeding. Developmental work was carried out during the year on a servomechanism for synchronizing the pulses from a magnetic drum with electronically generated pulses. Such a servo-mechanism will provide a means of effectively passing information between all existing types of memory unit. A considerable amount of work has been done also on the logical design of arithmetic units of fixed and floating point coded decimal and binary machines.

(*c*) *Composite Analogue and Digital Computers.*—Some preliminary work has been done by the Section of Mathematical Instruments on the problem of conversion of data from analogue to digital form and vice versa in order to explore the possibilities of composite type computing machines as well as the application of digital memory units to control systems generally. A final-year student in electrical engineering made a study of this subject during the year and submitted a thesis for his degree on "The quantization of analogue quantities to a binary digital code".

(*d*) *Electronic Decade Counter Tube.*—During the year a number of improvements in the design of the scale-of-ten counter tube developed in the Division of Electrotechnology were made and full working drawings, operating instructions, and other material have been prepared. Circuits for coupling between counters and resetting to zero have been developed.

A counter from 0 to 9,999 using four of the new scale-of-ten tubes has been built, which shows that a considerable saving in weight and size results from the low power consumption and simple circuits of these tubes.

An electron path computer has been built and put into operation.

(*e*) *Punched-card Computing Methods.*—Work on methods of computation using standard Hollerith punched-card equipment has been continued in the Division of Radiophysics and a number of computations have been carried out for this Division and for other bodies. The examples quoted below illustrate the diversity of problems to which punched-card methods have been or are being applied:—

(i) Time series analysis of radio astronomical data.

(ii) Fourier synthesis of X-ray diffraction data for the determination of crystal structure for the Division of Industrial Chemistry.

(iii) Computation of astronomical tables giving the zenith distance of the Sun at Sydney at any given time.

(iv) Computation of a class of functions similar to the sine and cosine integrals, but of a generalized nature.

(v) About 1,400 non-linear differential equations relating to water conservation have been solved at the request of the Snowy Mountains Hydro-electric Authority.

(vi) Computations relating to the flow of air around droplets and on the evolution of cloud structure have been made and further calculations are in progress.

(vii) Work on certain functions occurring in high-speed flow through nozzles is now under way for the University of Melbourne, as also are further astronomical tables and computations related to the successive integrals of the error functions, &c.

4. Servomechanisms and Control Systems.

Servomechanism studies by the Section of Mathematical Instruments are closely linked with the developments in computing machines. In addition to their application in this field, work has been done on their industrial application. The Section is at present developing a position control servomechanism for controlling the trimming knives of a Callender machine used in the rubber industry. Some attention is also being paid to the problem of speed control and a final-year student in Electrical Engineering designed and constructed an electronic speed controller for a ¼-horse-power motor.

XXXI. INFORMATION, LIAISON, AND LIBRARY SERVICES.

1. General.

Results from the Organization's research programme are made available in several ways to those interested in their application to the problems of industry.

Research results are published through scientific journals catering for the needs of the various branches of scientific endeavour, including specialist journals published overseas. The Organization publishes, in collaboration with the Australian National Research Council, the *Australian Journal of Scientific Research*, which is issued in two series, Series A dealing with the physical sciences and Series B with the biological

sciences. In collaboration with the Australian Institute of Agricultural Science and the Australian Veterinary Association, it publishes the *Australian Journal of Agricultural Research*. The Organization itself also publishes the *Australian Journal of Applied Science* and the *Australian Journal of Marine and Freshwater Research*. Longer reports are published in the Organization's Bulletin series. Trade circulars and newsletters are issued to provide industry with technological information and articles of a similar nature are prepared for trade publications. The Organization also collaborates with other bodies in the preparation of special pamphlets dealing with its research results.

The Divisions and Sections maintain close contact with the branches of industry to which their research programmes are related. Their information officers and technical secretaries answer many specific inquiries either from the accumulated experience of the scientific staffs of the laboratories, or from the literature. They are assisted in this work by the central Information Service and the associated Documentation and Translation Sections. These are located at the Head Office and their work is described in Sections 2–4 of this Chapter.

The Agricultural Research Liaison Section was established in February, 1951, at the Head Office, to assist in making results from agricultural research of the Organization available speedily to State Departments of Agriculture for use in their extension work. Its activities are described in Section 5. Contact between Australian agricultural scientists and the Commonwealth Agricultural Bureaux is assisted by the provision of the necessary secretarial facilities in the Head Office of the Organization.

As far as possible, direct contact is maintained with workers in overseas laboratories. This is helped considerably by visits overseas by members of the scientific staff, although the number of officers who can be sent for this purpose is limited. The liaison offices in the United Kingdom and North America, in addition to their work in interchange of scientific information, are able to assist greatly in the arrangement of visits of members of the research staff. Their activities are described in Section 6.

Reference libraries are established at the Head Office and in the Divisions and Sections, and developments during the year are reported in Section 7.

The film Unit, located at the Head Office, undertakes the production of cine films, as a means of showing the results of research work. Its activities are reported in Section 8.

2. Information Service.

During the year the Officer-in-charge of the Information Service resigned in order to accept an appointment with the Division of Industrial Development. Some changes in the administration of the Information Service followed, partly in the light of consideration given to that matter at a meeting of the Industrial and Physical Sciences Section of the Advisory Council held in November, 1950. The general feeling of that Section was that technical information should be given to industry by specialists actively associated with work in laboratories rather than by a centralized Information Service. It was emphasized that every effort should be made to increase the contacts between research workers of the Divisions and Sections and technologists in industry if Australia were to get the full advantage of the knowledge available in and the work done by the Organization's laboratories. On the other hand, it was realized that a small central Information Service would be required for handling inquiries in fields not covered by laboratory services, for passing other inquiries on to those libraries or laboratories best fitted to answer them, and for maintaining indexing and abstracting services.

It was decided not to replace the former Officer-in-Charge and thus to merge the administration of the Service rather more closely into the whole Head Office organization. Otherwise, the Service has carried on largely as in previous years and has been concerned mainly with the handling of specific inquiries, the preparation of technical reports, the dissemination of information received from overseas, and the preparation of summaries of information on specified subjects for the Executive.

(*a*) *Inquiries.*—As inquiries are now referred, where possible, to C.S.I.R.O. research units or other specialized information sources, the number of inquiries dealt with by the Information Service itself has diminished, although the total volume of inquiries was approximately the same as in the previous year.

(*b*) *Bibliographies and Technical Reports.*—Twelve bibliographies were prepared in dealing with inquiries, and were made available for distribution. A summary of information on vitreous enamelling was prepared and issued in the T series of reports. A survey of Australian metallurgical and geological laboratories, prepared by the Abstracting and Documentation Section, was also issued in this series. Numerous requests have been received for copies of these, and of earlier bibliographies and reports.

(*c*) *Central Information Service Activities.*—(i) *Dissemination of Information from Overseas.*—Procurement and distribution of information have continued as in previous years, although on a somewhat reduced scale.

(ii) *Reports from the Office of Technical Services, U.S.A.*—The P.B. series of reports, which was begun by the Office of Technical Services to make technical information from former enemy countries available to scientists, is being continued, and now includes much material relating to current research in the U.S.A. and in other countries. In some cases, the reports appear also in other forms, but often information in P.B. reports is not otherwise readily available. Thus although earlier it appeared likely that fewer requests for these reports would be received, there has been a steady demand for them, a large proportion of the requests being from the Organization's research units.

(iii) *Declassification of Reports of Australian Wartime Research.*—The declassification of these reports and transfer to the library of the Defence Research Laboratories of those still unclassified has been practically completed.

3. Documentation Section.

(*a*) *Scientific Abstracting.*—The Royal Australian Chemical Institute decided to discontinue *Australian Chemical Abstracts* as from the end of 1950. A cumulative index of abstracts for the years 1949 and 1950 has been prepared and is ready for publication. By special arrangement the Section recently undertook to act as a local office for *Chemical Abstracts*. A panel of specialist abstractors has been built up, and abstracts are regularly being forwarded. The Section has also arranged to abstract certain periodicals for *British Abstracts*.

(*b*) *Index to C.S.I.R.O. Publications.*—During the year a collection of reprints of papers published in external journals was built up. These have been author-indexed, and subject-indexing is proceeding. It is proposed to extend the collection to Divisional reports.

(*c*) *Phytochemical Register of Australian Flora.*—Nearly all the State groups have now completed their quotas of Australian literature to be searched for

phytochemical information, and the incoming data are being collated and filed. It is proposed to make a start on overseas literature as soon as the tentative list of journals submitted to the Phytochemical Conference has been finalized. The list is being circulated to State representatives for comment and suggestions.

(*d*) *Directories.*—Draft final entries for the directory of Australian scientific societies are being submitted for approval to the societies concerned and work on the directory of Australian research institutions is proceeding.

(*e*) *A.N.R.C. Committee on Scientific Information.*—During the year the Section leader served as Secretary to this Committee, which is concerned with implementing the recommendations of the Royal Society Scientific Information Conference of 1948, and has also been accepted by U.N.E.S.C.O. as the Australian Regional Committee on Scientific Abstracting.

4. Translation Section.

The Section has continued to undertake translation, written and oral, for C.S.I.R.O. Divisions and Sections. To this work has been added a very small amount of translation, mainly oral, for other governmental and scientific bodies. Some work has been sent to outside translators, partly owing to a temporary staff shortage, and partly because the languages were not covered by the translating staff.

An important duty has been the preparation of contents lists of Russian scientific periodicals, for the information of C.S.I.R.O. officers and for inclusion in the Translated Contents Lists of Russian Periodicals, issued by the Department of Scientific and Industrial Research of Great Britain. Copies of these lists are distributed to Public and University Libraries in the capital cities of Australia.

In connexion with the interchange of translations between countries of the British Commonwealth, a list of all translations hitherto made by the Section has been sent to the British Commonwealth Scientific Office, London, for reference. Lists of completed translations, of which copies can be supplied on demand, are being sent monthly for inclusion in the consolidated index being prepared by the B.C.S.O. These lists are distributed within C.S.I.R.O. and to certain other departments, and selections are made from them for publication in Australian technical and scientific periodicals.

The languages handled by the Translation Section are German, Dutch, Swedish, Norwegian, Danish, Icelandic, Latin, French, Italian, Spanish, Portuguese, Hebrew, Russian, Polish, Ukrainian, Lettish, and Hungarian. For other languages, use is made of a panel of outside translators.

5. Liaison between Agricultural Research and Extension Work.

The main purpose of the Agricultural Research Liaison Section is to ensure that results from agricultural research of the Organization are made available speedily to State Departments of Agriculture for use in their extension work with farmers.

This is being done first by marshalling available research information. Research officers are being consulted and, where necessary, conferences at a research level arranged. Material for practical use is being prepared and this requires discussion between research and extension officers at conferences or schools.

The first conference arranged by the Section was held in June to bring together research officers concerned with sheep and wool. Representatives of most State Departments of Agriculture, the East Sydney Technical College, and the Organization met in Sydney to discuss recent research findings and their presentation later in the year to a sheep and wool school to be organized by the Queensland Department of Agriculture and Stock in co-operation with the Organization. Following the Sydney conference the Section is preparing a handbook of basic research information as a reference book for the school, and will assist lecturers in preparing discussion sheet summaries and visual aids such as slides and charts.

6. Overseas Liaison Officers.

The Organization maintains Scientific Liaison Offices in London and Washington. These form constituent units of the British Commonwealth Scientific Office (London) and the British Commonwealth Scientific Office (North America). These joint offices provide common facilities for Scientific Liaison Officers from the British Commonwealth countries to work together in London and Washington.

The Organization's Liaison Offices play an important part in the interchange of scientific information, their functions including the handling of inquiries from Divisions and Sections, and the location and collection of relevant unpublished reports. They act also as bases for visiting officers of the Organization and as points of contact with research students. In addition they procure specialized equipment and apparatus, and in general act as links for the Organization with scientific work in the United Kingdom and North America.

7. Libraries.

The efficient handling of scientific and technical literature becomes more of a problem each year, more particularly when many Government departments, research institutions, and societies have decided to revise their methods of publication, to issue many new journals, and to change the titles and formats of those already being issued. The past year seems to have been a particularly bad one for alterations of this type and much valuable time has had to be spent in making the necessary adjustments.

The union author catalogue of Divisional holdings, which is held in Head Office, has increased rapidly and is now contained in 144 standard catalogue drawers. The principle of union catalogues is being extended. Divisions which have need for the same publications are recording each other's holdings in their respective catalogues. For example, the library in Geelong is maintaining a complete catalogue of all the material in the libraries of the other Wool Textile Research Laboratories situated in Melbourne and Sydney. It is also building up a useful specialist library of general textile literature. The Irrigation Research Station, Griffith, has a union catalogue of the holdings of the Commonwealth Research Station, Merbein, and the Regional Pastoral Laboratory, Deniliquin, as well as its own. These smaller union catalogues save considerable correspondence between the libraries concerned and Head Office.

There have been no major alterations in the general plan of organization of the libraries during the year and only one new branch library—that attached to the Wool Textile Research Laboratories, Physics and Engineering Unit, Sydney—has been formed.

Owing to unavoidable delays in procuring the necessary paper and arranging for printing the new edition of the "Catalogue of Scientific and Technical Periodicals in the Libraries of Australia" has not been completed, but it will be available for distribution before the end of 1951.

8. Film Unit.

During the year the following complete 16-millimetre sound films were released: "Caulking Compounds" (colour), "Science and Wood" (colour), "The Work and Facilities of the Division of Forest Products", and "Northern Australia Regional Surveys, Part II.—The Barkly Region" (black and white).

Two projects involving, at this stage, record filming only were begun: "Woollen and Worsted Research" and "Mutton Bird Investigations—Flinders Island".

The material obtained may be added to later and, if suitable, incorporated in release type films.

The following three films, being produced for the Murrumbidgee Irrigation Area Agricultural Service of the New South Wales Department of Agriculture, have been almost completed and will be released early in 1951-52: "The Origin and Control of Salting", "Farm Design and Grading", and "Supply and Drainage Ditches".

The film on the Ord-Victoria Rivers Area of Northern Australia will not be finished for some time, as survey work has not been completed.

During the year arrangements have been made for two copies of most of the films produced by C.S.I.R.O. to be held by the Australian National Library in Canberra, thus ensuring their wider availability in Australia and overseas. Copies of many films have also been obtained by the State Film Advisory Councils in five States of the Commonwealth. The film library of the Unit now holds 49 films, all of which are available for loan to approved educational authorities, film societies, and the like.

XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. Executive.

I. Clunies Ross, D.V.Sc. (*Chairman*).
F. W. G. White, M.Sc., Ph.D. (*Chief Executive Officer*).
S. H. Bastow, D.S.O., B.Sc., Ph.D.
H. J. Goodes, B.A.
A. B. Ritchie, M.A.

2. Advisory Council.

Chairman.

I. Clunies Ross, D.V.Sc.

Executive.

(*See* above.)

Chairmen of State Committees.

New South Wales—Professor J. P. Baxter, O.B.E., B.Sc., Ph.D.
Victoria—R. S. Andrews, D.Sc.
Queensland—A. F. Bell, M.Sc., D.I.C.
South Australia—Sir Kerr Grant, M.Sc.
Western Australia—Professor E. J. Underwood, B.Sc. (Agric.), Ph.D.
Tasmania—S. L. Kessell, M.B.E., M.Sc.

Co-opted Members.

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N.K.S. Brodribb, C.B.E., F.R.I.C.
Sir Harry Brown, C.M.G., M.B.E.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
Honorable O. McL. Falkiner, M.L.C.
W. A. Gunn.
W. S. Kelly, O.B.E.
E. H. B. Lefroy.
Sir John Madsen, B.E., D.Sc.
Professor D. M. Myers, D.Sc.
G. B. O'Malley, B.Met.E.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
Professor S. M. Wadham, M.A.
Professor J. G. Wood, Ph.D., D.Sc.

3. State Committees.

New South Wales.

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R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
A. R. Penfold.
Professor W. L. Waterhouse, M.C., B.Sc.Agr.
Professor J. D. Stewart, B.V.Sc.
Sir Frederick McMaster.
R. P. Okeden.
The Honorable Sir Norman Kater, M.L.C., M.B., Ch.M.
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J. Merrett.
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J. P. Tivey, B.A., B.Sc., B.E.
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Professor D. M. Myers, D.Sc.

Victoria.

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W. Baragwanath.
G. G. Jobbins.
Professor J. S. Turner, M.A., Ph.D., M.Sc.
Professor P. MacCallum, M.C., M.A., M.Sc., M.B., Ch.B.
Professor J. N. Greenwood, D.Sc., M.Met.E.
W. E. Wainwright.
L. J. Weatherly, M.A.
H. Herman, D.Sc., M.M.E., B.C.E.
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Professor E. J. Hartung, D.Sc.
N. K. S. Brodribb, C.B.E.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
Professor S. M. Wadham, M.A.
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D. T. Boyd, C.M.G.
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Associate Professor G. W. Leeper, M.Sc.
R. A. Hunt, D.S.O., B.C.E., M.I.E. Aust.

Queensland.

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R. Veitch, B.Sc.Agr., B.Sc.For.
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J. F. Meynink.
J. McCann.
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J. L. Wilson.
J. Michelmore.
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R. J. S. Muir.
R. J. Donaldson, D.S.O., B.C.E.
C. E. Young, D.S.O.
A. W. Campbell.

J. R. Duggan.
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B. Flewell-Smith, M.M.
R. L. Harrison.
C. H. Jamieson.
W. I. McLean.
Professor W. V. Macfarlane, M.A., M.D.
T. C. Marshall.
W. A. Mawby.
Professor M. Shaw, M.Eng., M.Mech.E.
Professor W. Stephenson, B.Sc., Ph.D.
S. A. Trout, M.Sc., Ph.D.
Professor H. C. Webster, D.Sc., Ph.D.
W. Webster, B.V.Sc.
Professor F. T. M. White, B.Met.E., B.E.
Associate Professor F. W. Whitehouse, Ph.D., D.Sc.
W. A. T. Summerville, D.Sc.
W. Young.

South Australia.

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C. Haselgrove.
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Western Australia.

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A. L. McKenzie Clark, L.V.Sc.
T. N. Stoate, M.Sc.
Professor A. D. Ross, M.A., D.Sc.
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F. G. Brinsden.
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Tasmania.

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Keith Brodribb.
T. A. Frankcomb.
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Professor H. N. Barber, M.A., Ph.D.
Professor J. C. Jaeger, M.A., D.Sc.

4. Committee of Review—Agricultural and Pastoral Problems.

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J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.
H. R. Marston, F.R.S., Division of Biochemistry and General Nutrition, C.S.I.R.O.
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A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
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5. Commonwealth Research Station, Merbein—Technical Committee.

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C. Barnard, D.Sc., Division of Plant Industry, C.S.I.R.O.
P. Malloch, Commonwealth Dried Fruits Control Board.
E. J. Casey, Commonwealth Dried Fruits Control Board.
J. R. Gordon, representing Consultative Committee.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

6. Commonwealth Research Station, Merbein.—Consultative Committee.

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H. Broadfoot, Department of Agriculture, New South Wales.
Hon. P. T. Byrnes, M.L.C., Woorinen, Victoria.
A. E. Cameron, Red Cliffs Settlement.
E. J. Casey, representing Technical Committee.
D. W. Cockcroft, Nyah-Woorinen Enquiry Committee.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
W. B. Hawson, First Mildura Irrigation Trust.
A. E. Hazel, Dried Fruits Association, Red Cliffs.
S. Heaysman, Coomealla, New South Wales.
W. Heaysman, Cardross Progress Association.
H. Jackson, Wakool Land-use Committee.
J. A. Lochhead, Mildura Shire Council.
A. R. McDougall, Merbein.
P. Malloch, representing Technical Committee.
R. C. Polkinghorne, Nyah-Woorinen Enquiry Committee.
F. Richardson, Nyah-Woorinen Enquiry Committee.
J. L. Showell, Renmark Irrigation Trust.

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S. P. Taylor, Curlwaa, New South Wales.
O. Weste, Renmark, South Australia.
D. C. Winterbottom, Mildura Packers' Association.
H. E. Wood, Dried Fruits Association, Woorinen.
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7. Wakool Land-use Committee.

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E. J. Williams, Rural Bank of New South Wales, Deniliquin.
K. Howe, Rural Bank of New South Wales, Deniliquin.
G. A. Crawford, Department of Agriculture, New South Wales.
K. Wood, Wakool District Landholders' Association.
D. Thomas, Wakool District Landholders' Association.
W. R. A. Smith, Wakool District Landholders' Association.
F. J. Hollins, Wakool District Landholders' Association.
L. A. Jeffers, Wakool District Landholders' Association.
F. Bock, Tullakool.
R. W. Prunster, B.Sc.(Agric.), Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
H. Jackson, Wakool District Landholders' Association (*Secretary*).

8. Irrigation Research Station, Griffith—Technical Committee.

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H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
V. C. Williams, representing Irrigation Research and Extension Committee.
E. S. West, B.Sc., M.S., Irrigation Research Station, Griffith (*Secretary*).

9. Irrigation Research and Extension Committee (Murrumbidgee Irrigation Areas).

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B. O. French, Yanco Experimental Farm.
J. M. Donald, Live Stock Officer (Sheep and Wool).
A. H. Skepper, H.D.A., Department of Agriculture, New South Wales.
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F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
R. W. Prunster, B.Sc.Agr., Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
H. Mallaby, H.D.A., Water Conservation and Irrigation Commission, New South Wales.
E. R. Iredale, Rural Bank of New South Wales.
G. E. B. Good, Rural Bank of New South Wales.
Professor J. R. A. McMillan, D.Sc.Agr., M.S., University of Sydney.
E. S. Clayton, H.D.A., Soil Conservation Service, New South Wales.
A. W. E. Harris, Yenda Producers' Co-op. Ltd.
H. J. Williams, Leeton Co-op. Cannery Ltd.
F. N. Walsh, Leeton Fruit Growers' Co-op. Soc. Ltd.
J. E. Morphett, Vegetable Growers' Association.
W. N. Hogan, M.I.A. District Council Extension Group.
P. Crook, M.I.A. District Council Extension Group.
G. S. Denne, M.I.A. District Council Extension Group.
A. D. McKellar, Rice Growers' Association, Leeton.
J. H. Reilly, Rice Growers' Association, Yenda.
T. Darchy, Rice Growers' Association, Murrami.
J. O. Doyle, Rice Marketing Board, New South Wales.
J. Woodside, Large Area Extension Groups, Griffith.
R. St. C. Young, Large Area Extension Groups, Yanco.

10. Regional Pastoral Centre, Deniliquin.—Technical Committee.

J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
L. B. Bull, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
H. R. Marston, Division of Biochemistry and General Nutrition, C.S.I.R.O.
J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.
T. J. Marshall, M.Ag.Sc., Ph.D., Division of Soils, C.S.I.R.O.
A. J. Vasey, B.Agr.Sc., Division of Animal Health and Production, C.S.I.R.O.
E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
O. McL. Falkiner, Boonoke Station, Conargo.
J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.
R. W. Prunster, B.Sc.(Agric.), Division of Plant Industry, C.S.I.R.O. (*Secretary*).

11. Regional Pastoral Centre, Armidale—Technical Advisory Committee.

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J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.
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G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.
J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.
R. Roe, B.Sc.(Agric.), Division of Animal Health and Production, C.S.I.R.O. (*Acting Secretary*).

12. Regional Pastoral Laboratory, Armidale—Consultative Committee.

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A. H. Voisey, D.Sc., New England University College.
A. G. Brett, Graziers' Association of New South Wales.
J. A. Nivison, Graziers' Association of New South Wales.
H. F. White, Graziers' Association of New South Wales.
D. P. Macansh, Northern New South Wales Farmers' Union.
L. P. Dutton, Council of Advice to the Pasture Protection Board, New South Wales.
Sir Hugh Croft, Council of Advice to the Pasture Protection Board, New South Wales.

S. Payne, Council of Advice to the Pasture Protection Board, N.S.W.
J. Ferris, Agricultural Bureau of New South Wales.
G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.
J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.
L. W. McLennan, B.Sc.Agr., New England Regional Development Committee.
J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.
R. Roe, B.Sc.(Agric.), Division of Animal Health and Production, C.S.I.R.O. (*Acting Secretary*).

13. "Gilruth Plains" Technical Committee.

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C. M. Donald, M.Ag.Sc., Division of Plant Industry, C.S.I.R.O.
R. B. Kelley, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
W. A. T. Summerville, D.Sc., Queensland Department of Agriculture and Stock.
W. Webster, B.V.Sc., Queensland Department of Agriculture and Stock.
J. F. Kennedy, M.Agr.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

14. Joint Blowfly Control Committee.

(Appointed as a means of co-ordinating the activities of the New South Wales Department of Agriculture, the Queensland Department of Agriculture and Stock, and the Organization.)
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A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
G. Edgar, D.V.Sc., Glenfield Veterinary Research Station, Department of Agriculture, New South Wales.
H. G. Belschner, D.V.Sc., Department of Agriculture, New South Wales.
T. McCarthy, Department of Agriculture, New South Wales.
W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

15. Joint Veterinary Parasitology Committee.

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J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
L. F. Hitchcock, M.Sc., Division of Entomology, C.S.I.R.O.
Miss H. F. Todd, C.S.I.R.O. (*Secretary*).

16. Queensland Producers' Animal Industry Committee.

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F. M. Bell, Queensland United Graziers' Association.
C. R. S. Smith, Queensland United Graziers' Association.
R. M. Bell, Queensland United Graziers' Association.
G. Woodburn, Queensland United Graziers' Association.
T. N. Pownall, Queensland United Graziers' Association.
J. F. Meynink, Queensland United Graziers' Association.
R. S. Wilson, Queensland United Graziers' Association.
J. L. Wilson, Queensland United Graziers' Association.
W. A. Gunn, Queensland United Graziers' Association.
W. G. Jones, Queensland United Graziers' Association.
C. H. Jamieson, Queensland Dairymen's State Council.
W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland.
M. White, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland.
G. R. Moule, B.V.Sc., Department of Agriculture and Stock, Queensland.
A. F. Bell, M.Sc., D.I.C., Department of Agriculture and Stock, Queensland.
F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.
L. F. Hitchcock, M.Sc., Division of Entomology, C.S.I.R.O.
T. B. Paltridge, B.Sc., Division of Plant Industry, C.S.I.R.O.
A. R. Riddle, A.B., M.S., Division of Food Preservation and Transport, C.S.I.R.O.
Professor W. V. Macfarlane, M.A., M.B., Ch.B., University of Queensland.
R. J. Donaldson, D.S.O., B.C.E., Brisbane.
Miss H. F. Todd, C.S.I.R.O. (*Secretary*).

17. Advisory Committee on Fruit Cool Storage Investigations in New South Wales.

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H. Broadfoot, Department of Agriculture, New South Wales.
Professor N. A. Burges, M.Sc., Ph.D., Department of Botany, University of Sydney.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
F. T. Bowman, Ph.D., M.Sc., B.Sc.Agr., Department of Agriculture, New South Wales.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

18. Committee for Co-ordination of Fruit and Vegetable Storage Research.

A. G. Strickland, C.B.E., M.Agr.Sc., Department of Agriculture, South Australia (*Chairman*).
W. J. Bettenay, B.Sc. (Agric.), Department of Commerce and Agriculture, Melbourne.
S. M. Sykes, B.Sc.Agr., Department of Agriculture, New South Wales.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
T. D. Raphael, M.A., Dip.Hort. (Cambridge), Department of Agriculture, Tasmania.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
D. Martin, B.Sc., Division of Plant Industry, C.S.I.R.O.
S. A. Trout, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
T. C. Miller, B.Sc., Department of Agriculture, Western Australia.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

19. Consultative Committee on Food Investigations and Standards.

J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O. (*Chairman*).
E. W. Hicks, B.A., B.Sc., Division of Food Preservation and Transport, C.S.I.R.O.

R. F. Turnbull, B.E., Division of Forest Products, C.S.I.R.O.
G. Loftus Hills, B.Agr.Sc., Dairy Research Section, C.S.I.R.O.
W. J. Bettenay, B.Sc.(Agric.), Department of Commerce and Agriculture, Melbourne.
W. J. Wiley, D.Sc., Department of Commerce and Agriculture, Melbourne.
H. R. Tinney, B.V.Sc., Department of Commerce and Agriculture, Melbourne.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

20. Committee for Co-ordination of Research on Fruit and Vegetable Processing.

J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O. (*Chairman*).
L. J. Lynch, B.Agr.Sc., Division of Food Preservation and Transport, C.S.I.R.O.
J. Shipton, B.Sc.Agr., Division of Food Preservation and Transport, C.S.I.R.O.
J. D. Bryden, H.D.A., Department of Agriculture, New South Wales.
A. C. Orman, H.D.A., Department of Agriculture, New South Wales.
H. R. Richardson, B.Sc.Agr., New South Wales Department of Agriculture.
E. G. Hallsworth, B.Sc., Ph.D., School of Agriculture, University of Sydney.
S. M. Sykes, B.Sc.Agr., Department of Agriculture, New South Wales.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

21. Dried Fruits Processing Committee.

A. G. Strickland, C.B.E., M.Agr.Sc., Department of Agriculture, South Australia (*Chairman*).
C. G. Savage, Department of Agriculture, New South Wales.
W. R. Jewell, M.Sc., B.Met., Department of Agriculture, Victoria.
W. M. Carne, Department of Commerce and Agriculture, Melbourne.
J. M. Davidson, B.V.Sc., Department of Commerce and Agriculture, Melbourne.
A. V. Lyon, M.Agr.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
E. C. Orton, B.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
D. G. Quinn, Department of Agriculture, Victoria.
B. G. Coombe, B.Agr.Sc., Department of Agriculture, South Australia (*Secretary*).

22. Advisory Committee on Fruit Storage—Investigations in Victoria.

C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria (*Convenor and Secretary*).
S. Fish, M.Agr.Sc., Department of Agriculture, Victoria.
J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.

23. Mildura District Dried Vine Fruits Processing Committee.

A. R. Hampton, representing Mildura Packers' Association (*Chairman*).
A. E. Hazel, Dried Fruits Association, Red Cliffs.
W. Heaysman, representing Merbein Advisory Committee.
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N. A. Johnson, Irymple, Victoria.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
K. H. C. McCallum, Red Cliffs, Victoria.
A. R. McDougall, Merbein, Victoria.
S. R. Mansell, Mildura, Victoria.
B. Bromley, Red Cliffs, Victoria.
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24. Advisory Committee on Red-legged Earth Mite Investigations, Western Australia.

E. H. B. Lefroy (*Chairman*).
C. F. Jenkins, B.A., Department of Agriculture, Western Australia.
I. Thomas, Department of Agriculture, Western Australia.
Professor E. J. Underwood, B.Sc. (Agric.), Ph.D., University of Western Australia.
A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
M. M. H. Wallace, B.Sc., Division of Entomology, C.S.I.R.O.
R. P. Roberts, M.Sc.(Agric.) (*Secretary*).

25. Kimberley Research Station Supervisory Committee.

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L. C. Snook, D.Sc., B.Sc.(Agric.), Animal Nutrition Officer, Western Australian Department of Agriculture.
C. M. Dimond, Public Works Department, Western Australia.
W. M. Nunn, Western Australian Department of Agriculture (Executive Officer).

26. Burdekin Investigations Committee.

W. A. T. Summerville, D.Sc., Queensland Department of Agriculture and Stock (*Chairman*).
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A. V. Hill, M.Agr.Sc., Division of Plant Industry, C.S.I.R.O.
W. G. Wells, Queensland Department of Agriculture and Stock.
J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O. (*ex officio* member).

27. Committee on Oenological Research.

Professor J. A. Prescott, C.B.E., D.Sc., F.R.S., representing C.S.I.R.O. (*Chairman*).
C. Haselgrove, representing the Federal Viticultural Council.
Professor J. B. Cleland, M.D., Ch.M., representing the University of Adelaide.
H. R. Haselgrove, representing the Australian Wine Board.

28. Fuel Research Advisory Committee.

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Professor C. E. Marshall, Ph.D., University of Sydney.
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L. J. Rogers, M.Sc., B.E., Department of Supply and Development.
C. R. Kent, B.Sc., Ph.D., D.I.C., Joint Coal Board.
R. P. Donnelly, Government Chemical Laboratory, Western Australia.
J. R. Duggan, B.Sc., B.E., Colonial Gas Association, Queensland.

H. R. Brown, B.Sc., Eng., Coal Research Section, C.S.I.R.O.
F. W. G. White, M.Sc., Ph.D., C.S.I.R.O.
I. W. Wark, D.Sc., Ph.D., Division of Industrial Chemistry, C.S.I.R.O.
A. B. Edwards, D.Sc., Ph.D., Mineragraphic Investigations, C.S.I.R.O.
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Associate Professor H. H. Dunkin, B.Met.E., School of Metallurgy, University of Melbourne.
R. B. Mills, B.Sc., Electrolytic Zinc Co. Ltd., Melbourne.
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30. Kalgoorlie Ore-dressing Sub-committee.

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F. G. Brinsden, Australian Institute of Mining and Metallurgy, Western Australia.
R. A. Hobson, B.Sc., School of Mines, Kalgoorlie, Western Australia.
J. R. Hylton, Great Boulder Pty. Gold Mines Ltd., Fimiston, Western Australia.

31. Mineragraphic Committee.

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33. Radio Research Board.

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Lieutenant-Colonel D. W. F. Small, Assistant Controller (Telecommunications), A.M.F.
Wing-Commander J. W. Reddrop, Director of Telecommunications and Radar, R.A.A.F.
R. v.d. R. Woolley, M.A., M.Sc., Ph.D., Mt. Stromlo Observatory.
Professor H. C. Webster, D.Sc., Ph.D., University of Queensland.
Professor L. G. H. Huxley, M.A., D.Phil., University of Adelaide.
G. P. Chippindall, Postmaster-General's Department.
E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.O.
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F. Loewe, Ph.D., University of Melbourne.
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35. Aviation Radio Research Committee.

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C. S. Wiggins, Department of Civil Aviation.
Wing-Commander J. W. Reddrop, Director of Telecommunications and Radar, R.A.A.F.
M. H. Myers, Qantas Empire Airways Ltd.
D. Stewart, B.E., Australian National Airways Ltd.
F. E. Coate, Australian National Airlines Commission.
E. P. Wright, B.Sc., Postmaster-General's Department.
Captain L. E. Morey, Australian Air Pilots' Association
F.W.G. White, M.Sc., Ph.D., C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Secretary*).

36. Building Research Committee.

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T. J. Cavanagh, Sydney.
D. V. Isaacs, M.C.E., Department of Works and Housing.
J. W. Drysdale, Department of Works and Housing.
R. E. Banks, Department of Works and Housing.
L. D. Wright, Department of Labour and National Service.
S. A. Clarke, B.E., Division of Forest Products, C.S.I.R.O.
W. F. Evans, B.Sc., Building Research Section, C.S.I.R.O. (*Secretary*).

37. Catalogue of Scientific and Technical Periodicals—Editorial Committee.

Leigh Scott, M.A., Librarian, University of Melbourne.
John Metcalfe, B.A., Principal Librarian, Public Library of N.S.W.
C. A. McCallum, B.A., Chief Librarian, Public Library, Melbourne.
Ellinor Archer, M.Sc., Chief Librarian, C.S.I.R.O.

XXXIII. STAFF.

The following is a list of the staff of the Organization as at 30th June, 1951. The list does not include clerical staff, typists, laboratory assistants, and miscellaneous workers.

1. Head Office.

(Head-quarters: 314 Albert-street, East Melbourne.)
Chairman—I. Clunies Ross, D.V.Sc.
Chief Executive Officer—F. W. G. White, M.Sc., Ph.D.
Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Secretary—G. A. Cook, M.C., M.Sc., B.M.E.
Assistant Executive Officer—H. C. Forster, M.Agr.Sc., Ph.D.
Assistant Secretary—F. G. Nicholls, M.Sc.
Assistant Secretary—G. B. Gresford, B.Sc.
Assistant Secretary—W. Ives, M.Ec., A.I.C.A.
Assistant Secretary (Finance and Supplies)—M. G. Grace, A.I.C.A.
Senior Research Officer—D. T. C. Gillespie, M.Sc.
Senior Research Officer—J. F. H. Wright, B.Sc.

Research Officer—P. F. Butler, M.Sc.Agr.
Research Officer—Miss J. Dunstone, B.Sc., Dip. Ed.
Architect—W. R. Ferguson, B.E.
Assistant to Architect—N. Schmidt.
Electrical and Mechanical Engineer—R. N. Morse, B.Sc., B.E.
Electrical Engineer—A. McLean, B.E.E.

Editorial—
Editor—N. S. Noble, D.Sc.Agr., M.S., D.I.C.
Senior Research Officer—R. W. Bond, B.Sc.
Research Officer—Miss L. F. Plunkett, B.Sc.
Research Officer—Miss M. Walkom, B.A.
Technical Officer—D. H. Tuck, B.Sc.

Library—
Chief Librarian—Miss E. Archer, M.Sc.
Librarian—Miss A. L. Kent.
Librarian—Miss F. V. Murray, M.Sc.
Librarian—Miss J. Conochie, B.Sc.
Librarian—Miss B. C. L. Doubleday, M.A.
Assistant Librarian—Miss J. Rosenberg, B.A.
Assistant Librarian—Miss T. Koetsier, B.A.

Accounts, Stores—
Accountant—D. J. Bryant, A.F.I.A.
Sub-Accountant—R. W. Viney, A.I.C.A., A.C.I.S.

Orders and Transport—
J. M. Derum.

Staff—
Staff and Industrial Officer—H. E. Waterman, A.F.I.A.
R. D. Elder.

Records—
P. Knuckey.

Central Experimental Workshops—
Engineer-in-charge—F. G. Hogg, B.E.
Design Engineer—K. A. Robeson, B.Mech.E.
Assistant Engineer—J. Kowalczewski, Dipl.Ing.
Chief Draughtsman—G. T. Stephens, Dip.Mech.Eng., Dip.Elec.Eng.

Liaison Overseas—
London—
Chief Scientific Liaison Officer—J. E. Cummins, B.Sc., M.S.
Principal Research Officer—I. L. Johnstone, B.V.Sc.
Senior Research Officer — A. B. Hackwell, B.Agr.Sc.
Washington—
Senior Research Officer—T. C. Bell, B.Agr.Sc.

Information Service—
Research Officer—R. W. Crabtree, B.Sc.
Research Officer—Miss J. McL. Baldwin, B.Sc., Dip.Ed.
Research Officer—G. J. Walker, M.Sc.
Technical Officer—Miss I. H. Robertson, M.Sc., D.A.C.

Documentation Section—
Research Officer—G. J. Wylie, B.A., B.Sc.
Technical Officer—Miss G. M. Lesslie, B.Sc.

Translation Section—
Senior Translator—A. L. Gunn.
Translator—E. Feigl, Ph.D.
Translator—Mrs. M. Slade.
Translator—Miss P. A. Gibson, B.A.
Translator—H. E. Kylstra, B.A.
In Sydney—
Translator—C. Wouters, D. ès L.

Film Unit—
Research Officer—S. T. Evans, B.Sc.

Agricultural Research Liaison Section—
Officer-in-charge—R. R. Pennefather, B.Agr.Sc.
Research Officer—A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D.

2. Secretaries of State Committees.

New South Wales—
A. M. Andrews, B.Sc., Phillip House, 119 Phillip-street, Sydney.

Victoria—
F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.

Queensland—
Miss H. F. Todd, 113 Eagle-street, Brisbane.

South Australia—
J. Ward Walters, Division of Biochemistry and General Nutrition, University of Adelaide.

Western Australia—
R. P. Roberts, M.Sc. (Agric.), Department of Agriculture, Perth.

Tasmania—
D. Martin, B.Sc., "Stowell", Stowell-avenue, Hobart.

3. Division of Animal Health and Production.

(Head-quarters: Cr. Flemington-road and Park-street, Parkville, Melbourne.)

At Divisional Head-quarters, Melbourne—
Chief—L. B. Bull, D.V.Sc.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.
Assistant Divisional Secretary—N. M. Tulloh, B.Agr.Sc.
Clerk—J. J. Foley.

At Animal Health Research Laboratory, Melbourne—
Assistant Chief of Division and Officer-in-charge—A. W. Turner, O.B.E., D.Sc., D.V.Sc.
Principal Research Officer (bacteriology)—T. S. Gregory, B.V.Sc., Dip. Bact.
Principal Research Officer (pathology, bacteriology, dairy cattle)—D. Murnane, D.V.Sc.
Senior Research Officer (bacteriology, beef cattle)—A. D. Campbell, L.V.Sc.
Senior Research Officer (physiology)—R. H. Watson, D.Sc.Agr.
Senior Research Officer (organic and immunochemistry)—A. T. Dann, M.Sc.
Senior Research Officer (chemical pathology and bacteriology)—A. T. Dick, M.Sc.
Senior Research Officer (bacteriology, dairy cattle)—E. Munch-Petersen, M.Sc., B.A., M.I.F.
Research Officer (microbiological chemistry)—A. W. Rodwell, M.Sc., Ph.D.
Research Officer (microbiological chemistry)—Mrs. E. S. Rodwell, M.A., Ph.D.
Research Officer (chemical pathology and analytical chemistry)—J. B. Bingley, D.A.C.
Research Officer (bacteriology)—Miss C. E. Eales, B.Sc.
Research Officer (bacteriology)—Miss M. J. Monsbourgh, B.Sc.
Research Officer (dairy cattle physiology)—H. G. Turner, B.Agr.Sc.
Research Officer (physiology)—G. Alexander, B.Agr.Sc. (on study leave).
Research Officer (physiology)—H. M. Radford, B.Sc.
Research Officer (clinical biochemistry)—Miss V. E. Hodgetts, B.Sc.
Research Officer (physiology)—J. S. McKenzie, B.Sc.
Technical Officer—M. W. Mules.
Technical Officer—E. Wold.
Technical Officer—A. E. Wright.
Technical Officer—J. J. Spencer.
Technical Officer—R. A. Fookes.
Technical Officer—N. E. Southern.
Technical Officer—I. S. Goldman.
Librarian—Miss F. V. Murray, M.Sc. (part-time).

Survey of Beef Cattle Production—
Senior Research Officer—W. A. Beattie, M.A., LL.B.

At Field Station, Werribee, Victoria—

Dairy Cattle Investigations—
Technical Officer—L. C. Gamble.

Poultry Breeding Investigations—
Senior Research Officer—F. Skaller, B.Agr.Sc., B.Com. (on leave).
Research Officer—J. A. Morris, B.Sc.Agr.
Research Officer—G. W. Grigg, M.Sc. (on study leave).
Technical Officer—T. E. Allen, B.Sc.
Technical Officer—W. J. Lloyd.

At McMaster Animal Health Laboratory, Sydney—
Assistant Chief of Division and Officer-in-charge—D. A. Gill, M.R.C.V.S., D.V.S.M.
Principal Research Officer (parasitology)—H. McL. Gordon, B.V.Sc.
Principal Research Officer (biochemistry)—M. C. Franklin, M.Sc., Ph.D.
Senior Research Officer (helminth physiology, parasitology)—W. P. Rogers, M.Sc., Ph.D.
Senior Research Officer (bacteriology)—D. F. Stewart, B.V.Sc., Dip. Bact.
Senior Research Officer (biochemistry)—C. R. Austin, M.Sc., B.V.Sc.
Research Officer (biochemistry)—R. L. Reid, B.Sc.Agr., Ph.D.
Research Officer (parasitology)—B. A. Forsyth, B.V.Sc.
Research Officer (biochemistry)—W. K. Warburton, LL.B., B.Sc.
Research Officer (physiology)—A. W. H. Braden, B.Sc.
Research Officer (helminth physiology, parasitology)—V. Massey, B.Sc. (on study leave).
Research Officer (ectoparasites)—Miss T. M. Scott, B.Sc.
Research Officer (parasitology) — R. I. Sommerville, M.Sc.Agr.
Research Officer (helminth physiology, parasitology)—Miss H. B. Esserman, B.Sc.
Ian McMaster Research Scholar—P. R. Whitfield, B.Sc.
Ian McMaster Research Scholar—P. K. Briggs, B.Sc.Agr.
Technical Officer—H. A. Offord.
Technical Officer—F. J. Hamilton.
Technical Officer—H. V. Whitlock.
Technical Officer—G. C. Merritt.
Technical Officer—A. C. Juleff.
Technical Officer—B. L. Campbell.
Clerk—H. H. Wilson.
Librarian—Miss A. G. Culey, M.Sc.

At Wool Biology Laboratory, Sydney—
Officer-in-charge (wool biology)—H. B. Carter, B.V.Sc.
Research Officer (tissue culture)—Miss M. H. Hardy, M.Sc., Ph.D.
Research Officer (wool biology)—K. Ferguson, B.V.Sc. (on study leave).
Research Officer (tissue culture)—Miss P. Davidson, B.Sc.
Research Officer (wool biology)—B. F. Short, M.Sc.Agr.
Research Officer (physiology)—J. H. Elliott, B.Sc.
Technical Officer—D. L. Hall.
Technical Officer—W. H. Clarke.

Sheep Breeding Investigations—
Research Officer—A. A. Dunlop, M.Agr.Sc., Ph.D.

At Fleece Analysis Laboratory, Villawood, New South Wales—
Officer-in-charge (wool metrology)—N. F. Roberts, M.Sc.
Research Officer (wool metrology)—L. T. Wilson, B.Sc.
Technical Officer—Miss L. Folley.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Officer-in-charge (parasitology, field stndies)—I. L. Johnstone, B.V.Sc. (on leave).
Acting Officer-in-charge (agrostology)—R. Roe, B.Sc.(Agric.).
Research Officer (animal husbandry)—J. F. Barrett, B.V.Sc.
Research Officer (parasitology)—W. H. Southcott, B.V.Sc.
Technical Officer (overseer)—V. D. Prentice, O.B.E.
Technical Officer—P. B. Sutton.
Technical Officer—Miss L. C. Lawrence (on leave).
Technical Officer—R. J. Lewis.
Technical Officer—J. W. Carr.
Technical Officer—R. L. Rocks.

At F. D. McMaster Field Station, Badgery's Creek, New South Wales—
Assistant Chief of Division and Officer-in-charge (animal genetics)—R. B. Kelley, D.V.Sc.
Research Officer (sheep breeding)—R. H. Hayman, B.Agr.Sc.

At Veterinary Parasitology Laboratory, Yeerongpilly, Queensland—
Officer-in-charge (parasitology)—F. H. S. Roberts, D.Sc.
Research Officer (parasitology)—P. H. Durie, B.Sc.
Research Officer (entomology, pathology)—R. S. Rick, B.V.Sc.
Technical Officer—R. K. Keith.

Survey of Fine Wool Production—
Senior Research Officer—J. H. Riches, B.Sc.Agr., Ph.D.

Cattle Breeding Investigations—
Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.

At Department of Physiology, University of Queensland, Brisbane—
Research Officer (physiology)—N. T. M. Yeates, B.Sc.Agr., Ph.D.

At National Field Station, "Gilruth Plains", Cunnamulla, Queensland—
Officer-in-charge (sheep breeding)—J. F. Kennedy, M.Agr.Sc.
Research Officer (sheep breeding)—C. H. S. Dolling, B.Agr.Sc., R.D.A.
Technical Officer (overseer)—P. H. G. Sheaffe.
Technical Officer—F. J. Willett.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Senior Research Officer (biochemistry)—A. B. Beck, M.Sc.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—

Sheep Breeding Investigations—
Technical Officer—F. S. Richardson, B.Agr.Sc.

4. Atomic Physics.

At University of Melbourne—

Research Officer—W. B. Lasich, M.Sc. (on study leave).
Research Officer—J. R. Prescott, B.Sc., Ph.D. (on study leave).
Research Officer—J. H. Parry, M.Sc.

Tracer Elements Unit (at Commonwealth X-ray and Radium Laboratory, Melbourne)—

Principal Research Officer—T. H. Oddie, D.Sc.
Research Officer—A. M. Downes, M.Sc.
Research Officer—K. R. Lynn, B.Sc.

At University of Tasmania—

Research Officer—D. W. P. Burbury, B.Sc.

At Atomic Energy Research Establishment, Harwell, England—

Principal Research Officer—O. O. Pulley, B.Sc., B.E., Ph.D.
Senior Research Officer—C. D. Boadle, B.M.E.
Senior Research Officer—J. N. Gregory, M.Sc.
Senior Research Officer—R. H. Myers, M.Sc., Ph.D.
Senior Research Officer—G. L. Miles, B.A., M.Sc., Ph.D.
Research Officer—N. A. Faull, B.Sc.
Research Officer—D. F. Sangster, B.Sc.

5. Division of Biochemistry and General Nutrition.

(Head-quarters: University of Adelaide.)

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Divisional Secretary—J. Ward Walters.
Principal Research Officer—A. W. Peirce, D.Sc.
Principal Research Officer—D. S. Riceman, M.Sc., B.Agr.Sc.
Senior Research Officer—E. W. Lines, B.Sc.
Senior Research Officer—H. J. Lee, M.Sc.
Senior Research Officer—F. V. Gray, M.Sc.
Senior Research Officer—Miss M. C. Dawbarn, M.Sc. (part-time).
Research Officer—I. G. Jarrett, M.Sc.
Research Officer—G. B. Jones, M.Sc.
Research Officer—T. A. Quinlan-Watson, M.Sc.
Research Officer—L. J. Frahn, M.Sc., Ph.D.
Research Officer—Miss S. H. Allen, B.Sc.
Research Officer—Miss P. Macbeth, B.Sc.
Research Officer—A. F. Pilgrim, B.Sc.
Research Officer—B. J. Potter, M.Sc.
Research Officer—J. K. Powrie, M.Sc., B.Sc.(Agric.).
Research Officer—R. M. Smith, B.Sc.
Research Officer—R. A. Weller, B.Sc.
Research Officer—R. E. Kuchel, B.Sc.
Senior Technical Officer—D. W. Dewey.
Technical Officer—R. E. Underdown, A.S.A.S.M.
Technical Officer—R. M. Sangster, R.D.A.
Technical Officer—V. A. Stephen.
Technical Officer—J. O. Wilson (part-time).
Technical Officer—D. F. Graham.
Technical Officer—C. E. Sleigh.
Technical Officer—R. F. Trowbridge.
Assistant Librarian—Miss P. M. Smith.
Farm Manager—R. H. Jones, R.D.A.

6. Division of Building Research.

(Head-quarters: Graham-road, Highett, Victoria.)

Administration—

Chief—I. Langlands, M.Mech.E., B.E.E.
Technical Secretary—W. F. Evans, B.Sc.

Information and Library—

Senior Research Officer—J. R. Barned, B.Sc.
Research Officer—R. C. McTaggart, B.Sc.
Research Officer (part-time)—Mrs. C. M. Petrie, M.A., Ph.D.
Technical Officer (photography)—E. S. Smith.
Librarian—Miss S. A. Hammill.

Physical and Mechanical Testing Laboratory—

Research Officer—R. E. Lewis, B.Sc.
Technical Officer—F. D. Beresford.
Technical Officer—W. U. S. Falk, F.M.T.C.
Technical Officer—Miss V. R. Goullet.

Concrete Investigations—

Research Officer—F. A. Blakey, B.E., Ph.D.
Research Officer—W. H. Taylor, M.C.E.
Technical Officer—E. N. Mattison.

Masonry Investigations—

Principal Research Officer—J. S. Hosking, M.Sc., Ph.D.
Senior Research Officer—H. V. Hueber, Dr.Phil.
Research Officer—W. F. Cole, M.Sc., Ph.D.
Research Officer—J. A. Ferguson, M.Sc., Ph.D.
Research Officer—R. D. Hill, B.Sc., B.Com.
Research Officer—Mrs. T. Demediuk, Dr.Phil.
Technical Officer—A. R. Carthew, B.Sc.
Technical Officer—Miss M. E. Neilson, B.Sc.
Technical Officer—A. E. Holland, A.M.T.C.
Technical Officer—Miss A. Feldman.

Surfacing Materials Investigations—

Senior Research Officer—E. H. Waters, M.Sc.
Research Officer—J. M. Hutson, M.A., B.Sc.
Research Officer—J. E. Bright, B.Sc.
Technical Officer—D. A. Powell, B.Sc.
Technical Officer—I. McLachlan.
Technical Officer—G. H. Price, B.Sc.

Acoustics and Thermal Investigations—

Senior Research Officer—R. W. R. Muncey, B.E.E.
Research Officer—A. F. B. Nickson, M.Sc.
Research Officer—W. K. R. Lippert, Dr.Phil.
Research Officer—T. S. Holden, B.Sc.
Technical Officer—A. W. Wilson.
Technical Officer—J. J. Russell.

Organic Materials Investigations—

Senior Research Officer—B. M. Holmes, M.Sc.
Research Officer—E. R. Ballantyne, B.Sc.
Research Officer—J. J. Greenland, B.Sc.(App.).
Technical Officer—N. G. Brown, A.M.T.C.
Technical Officer—J. W. Spencer, B.Sc.

Drawing Office—

Sectional Draughtsman—G. T. Stephens, Dip. Mech.Eng., Dip.Elec.Eng.

7. Coal Research Section.

(Head-quarters: Delhi-road, North Ryde, New South Wales.)

Officer-in-charge—H. R. Brown, B.Sc.Eng.
Assistant Librarian—Miss J. M. Hazlitt, B.A.
Senior Research Officer—H. Berry, M.Sc.(Tech.).
Research Officer—R. H. Jones, B.Sc.
Senior Technical Officer—M. S. Burns.
Senior Technical Officer—O. Morris.
Technical Officer—H. F. A. Hergt, A.M.T.C.
Technical Officer—A. Wlasow, Dip.Chem., Dip.Ing.
Technical Officer—H. N. S. Schafer, B.Sc.
Technical Officer—T. P. Maher, B.Sc.
Technical Officer—A. J. Ryan, B.Sc.
Technical Officer—Mrs. B. J. Nivison-Smith, B.Sc.
Technical Officer—J. P. F. Hennelly, B.Sc.

8. Commonwealth Research Station (Murray Irrigation Areas).

(Head-quarters: Merbein, Victoria.)

Officer-in-charge—F. Penman, M.Sc.
Principal Research Officer—E. C. Orton, B.Sc.
Senior Research Officer—J. G. Baldwin, B.Sc., B.Agr.Sc.
Research Officer—G. V. F. Clewett, B.E.
Research Officer—W. J. Webster, B.Sc.

Research Officer—A. J. Antcliff, B.Sc.
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—S. F. Bridley, B.Agr.Sc.
Research Officer—R. C. Woodham, B.Agr.Sc.
Research Officer—D. M. Alexander, B.Sc.
Research Officer—L. R. Finch, B.Sc. (on study leave).
Senior Technical Officer—J. E. Giles.
Technical Officer—G. L. Stott, A.S.T.C.
District Officer (Nyah-Woorinen)—R. C. Polkinghorne (part-time).
District Officer (Wakool)—H. Jackson (part-time).
District Officer (Renmark)—J. V. Seekamp, B.Agr.Sc. (part-time).

9. Dairy Research Section.

(Head-quarters: Lorimer-street, Fishermen's Bend, Victoria.)

Officer-in-charge—G. Loftus Hills, B.Agr.Sc.
Principal Research Officer—N. King, M.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Senior Research Officer—K. Kumetat, Ph.D.
Research Officer—J. Conochie, B.Sc. (Agric.).
Research Officer—A. J. Lawrence, B.Sc.
Research Officer—D. A. Forss, M.Sc.
Research Officer—J. Czulak, B.Sc. (Agric.).
Research Officer—J. W. Lee, B.Sc.

10. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—F. J. Lehany, M.Sc. (abroad).
Acting Chief—A. M. Thompson, B.Sc.
Technical Secretary—R. C. Richardson, B.E.
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—W. K. Clothier, B.Sc., M.E.
Senior Research Officer—R. J. Meakins, B.Sc., Ph.D.
Senior Research Officer—R. A. Sack, B.Sc., Ph.D.
Senior Research Officer—B. V. Hamon, B.Sc., B.E.
Senior Research Officer—D. L. Hollway, B.E.E., M.Eng.Sc.
Research Officer—L. Medina, Dipl.Ing.
Research Officer—D. C. Pawsey, B.E.E.
Research Officer—J. S. Dryden, M.Sc., Ph.D.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—P. G. Walker, B.Sc.
Research Officer—T. M. Palmer, Dipl.F.H.
Research Officer—H. K. Welsh, M.Sc.
Research Officer—D. W. Posener, M.Sc.
Research Officer—Miss J. W. Mulley, A.S.T.C.
Research Officer—D. G. Lampard, B.Sc.
Research Officer—J. J. O'Dwyer, B.Sc., B.E. (abroad).
Research Officer—D. L. H. Gibbins, B.E. (abroad).
Senior Technical Officer—L. M. Mandl, Dpl.Ing., A.S.T.C.
Senior Technical Officer—F. C. Brown, A.S.T.C.
Technical Officer—R. W. Archer, A.S.T.C.
Technical Officer—H. A. Smith, A.S.T.C.
Technical Officer—R. V. Single.
Technical Officer—H. C. Collins, A.S.T.C.
Technical Officer—J. M. Melano, A.S.T.C.
Technical Officer—Miss M. C. Clark, B.Sc., A.S.T.C.
Technical Officer—H. Bairnsfather.
Technical Officer—E. Cowcher, B.A., A.S.T.C.
Technical Officer—Miss P. M. G. Thompson, B.Sc.
Technical Officer—P. C. Nolan, B.Sc.

11. Division of Entomology.

(Head-quarters: Canberra, Australian Capital Territory.)

At Canberra—
Administration—
Chief—A. J. Nicholson, D.Sc.
Technical Secretary—K. L. Taylor, B.Sc.Agr.
Librarian (half-time)—Miss J. Humphreys, B.A., Dip.Ed.
Senior Clerical Officer (half-time)—K. J. Prowse.
Accountant (half-time)—D. W. Banyard.
Illustrator—L. A. Marshall.
Photographer—D. H. Wilson.

Biological Control—
Principal Research Officer—F. Wilson.
Research Officer—E. F. Riek, M.Sc.
Research Officer—G. J. Snowball, B.Sc.
Technical Officer—G. R. Wearne.

Museum—
Research Officer—T. G. Campbell.

Taxonomy of Diptera—
Senior Research Officer—S. J. Paramonov, D.Sc.

Physiology and Toxicology—
Principal Research Officer—D. F. Waterhouse, M.Sc.
Senior Research Officer—D. Gilmour, M.Sc.
Research Officer—R. F. Powning, A.S.T.C.
Technical Officer—L. G. Webber, B.Sc.
Technical Officer—H. Irzykiewicz.
Technical Officer—Mrs. M. M. Goldberg, B.Sc.

Insecticide Investigations—
Research Officer—R. W. Kerr, B.Sc. (abroad).

Locust and Pasture Pests—
Principal Research Officer—K. H. L. Key, D.Sc.
Research Officer—P. B. Carne, B.Agr.Sc.
Technical Officer—L. J. Chinnick, R.D.A.

Virus Vector Investigations—
Senior Research Officer—M. F. Day, B.Sc., Ph.D.
Research Officer—A. L. Dyce, B.Sc.Agr.
Technical Officer—N. E. Grylls, D.D.A.
Technical Officer—Miss A. K. McKinnon, B.Sc.

Termite Investigations—
Senior Research Officer—F. J. Gay, B.Sc., D.I.C.
Technical Officer—A. Wetherley.

Sheep Blowfly Investigations—
Senior Research Officer—K. R. Norris, M.Sc.
Technical Officer—K. Laucis.

Ant Investigations—
Research Officer—T. Greaves.

Population Dynamics—
Chief of Division—A. J. Nicholson, D.Sc.
Senior Technical Officer—A. T. Mills.
Technical Officer—S. Dee.

Pasture Caterpillar Investigations—
Research Officer—I. F. P. Common, M.A., B.Agr.Sc.

Pests of Stored Products—
Research Officer—S. W. Bailey, B.Sc., A.R.C.S.

At Yeerongpilly, Queensland—
Cattle Tick Investigations—
Senior Research Officer—L. F. Hitchcock, M.Sc.
Research Officer—W. J. Roulston, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.

At Rockhampton, Queensland—
Cattle Tick Investigations—
Research Officer—P. R. Wilkinson, M.A.
Technical Officer—J. T. Wilson, Q.D.A.

In Western Australia—
Earth Mite Investigations—
Research Officer—M. M. H. Wallace, B.Sc.
Technical Officer—J. A. Mahon, Dip.D.Sci.

At Bright, Victoria—
St. John's Wort Investigations—
Senior Research Officer—L. R. Clark, M.Sc.

12. Division of Fisheries.

(Head-quarters: Cronulla, New South Wales.)

At Cronulla—
Chief—H. Thompson, M.A., D.Sc.
Technical Secretary—Mrs. L. M. Willings, B.A.

Senior Principal Research Officer—G. W. Rayner, M.Sc.
Principal Research Officer (bacteriologist)—E. J. Ferguson Wood, B.A., M.Sc.
Senior Research Officer (biologist)—M. Blackburn, M.Sc.
Senior Research Officer (chemist and hydrologist)—D. J. Rochford, B.Sc. (abroad).
Research Officer (biologist)—I. S. R. Munro, M.Sc.
Research Officer (ichthyologist)—A. M. Rapson, M.Sc.
Research Officer (chemist and hydrologist)—R. S. Spencer, B.Sc.
Research Officer (biologist)—G. S. Grace, B.Sc.
Research Officer (planktologist)—Miss P. Kott, M.Sc. (abroad).
Research Officer (algologist)—A. B. Cribb, B.Sc.
Technical Officer (biologist)—J. P. Robins, B.Sc.
Technical Officer—F. E. Allen.
Marine Superintendent—Commander R. H. Thornton (abroad).
Senior Technical Officer (Laboratory)—A. Proctor.
Technical Officer (laboratory)—G. A. Gordon.
Gear Officer—A. Temple.

At Melbourne—

Technical Officer (biologist)—P. E. Gartner, B.Sc.

At Perth—

Senior Research Officer (officer-in-charge, biologist)—D. L. Serenty, B.Sc., Ph.D.
Research Officer (biologist)—K. Sheard, M.Sc.
Research Officer (biologist)—W. B. Malcolm, B.Sc.
Research Officer (biologist)—R. G. Chittleborough, B.Sc.
Technical Officer (hydrologist)—H. R. Jitts, B.Sc.
Technical Officer—A. Middleton.

At Hobart—

Senior Research Officer (biologist)—A. G. Nicholls, B.Sc., Ph.D.
Research Officer (biologist)—A. M. Olsen, M.Sc.
Research Officer (biologist)—A. H. Weatherley, B.Sc.

At Dunwich, Queensland—

Research Officer (biologist)—J. M. Thomson, M.Sc.

At Thursday Island, Queensland—

Research Officer (biologist)—J. S. Hynd, B.Sc.

13. Flax Research Section.

(Head-quarters: Graham-road, Highett, Victoria.)
Officer-in-charge—W. L. Greenhill, M.E.
Senior Research Officer—Miss J. F. Couchman, B.Sc.
Senior Research Officer—G. W. Lanigan, M.Sc.
Research Officer—K. Stiebris, D.Sc.
Research Officer—W. Shepherd, B.Sc., B.Ag.Sc.
Technical Officer—M. Tisdall.

14. Division of Food Preservation and Transport.

(Head-quarters: State Abattoir, Homebush Bay, New South Wales.)

At Homebush, New South Wales—

Administration and General—

Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary—R. B. Withers, M.Sc., Dip.Ed.
Librarian—Miss B. Johnston, B.Sc. (abroad).
Assistant Librarian—Miss J. Hicks.
Maintenance Engineer—T. L. Swan.

Physics and Transport Section—

Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Senior Research Officer—M. C. Taylor, M.Sc.
Research Officer—G. M. Rostos, Dipl.Ing.
Technical Officer—M. B. Smith, A.S.A.S.M.
Technical Officer—J. Mellor.

Microbiology Section—

Principal Research Officer—W. J. Scott, B.Agr.Sc.
Research Officer—M. R. J. Salton, M.Sc.Agr. (abroad).
Research Officer—W. G. Murrell, B.Sc.Agr. (abroad).
Technical Officer—P. R. Maguire.
Technical Officer—D. F. Ohye, D.I.C.
Technical Officer—Miss B. J. Marshall, A.S.T.C.

Biochemistry Section—

Senior Research Officer—F. E. Huelin, B.Sc., Ph.D.
Technical Officer—R. A. Gallop, A.S.T.C.

Organic Chemistry Section—

Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Technical Officer—Miss N. Wonders, A.S.T.C.

Fruit and Vegetable Storage Section—

Principal Research Officer—R. N. Robertson, B.Sc., Ph.D.
Senior Research Officer—E. G. Hall, B.Sc.Agr.
Research Officer—J. F. Turner, M.Sc. (abroad).
Technical Officer—T. J. Riley, H. D. A.

Canning and Fruit Products Section—

Principal Research Officer—L. J. Lynch, B.Agr.Sc.
Senior Research Officer—J. F. Kefford, M.Sc.
Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—B. V. Chandler, B.Sc.
Research Officer—E. G. Davis, B.Sc.
Research Officer—P. W. Board, B.Sc.
Technical Officer—D. Moyes, B.Sc.Agr.

Dried Foods Section—

Research Officer—J. Shipton, B.Sc.Agr.
Research Officer—D. McG. McBean, B.Sc.
Technical Officer—F. Fitzpatrick, A.S.T.C.

Fish Investigations—

Principal Research Officer—W. A. Empey, B.V.Sc.
Technical Officer—R. Allan.
Technical Officer—K. W. Anderson, A.M.T.C.
Technical Officer—Mrs. H. S. Wallace, A.S.T.C.

Meat and Egg Investigations—

Senior Research Officer—A. R. Riddle, A.B., M.S.
Technical Officer—F. S. Shenstone, A.S.T.C.

Freezing of Fruit and Vegetables—

Research Officer—I. J. Tinsley, B.Sc.

At Auburn, New South Wales—

Meat Dehydration Investigations—

Research Officer—A. R. Prater, B.Sc.Agr.

At Botany School, University of Sydney—

Plant Cell Physiology Investigations—

Principal Research Officer—R. N. Robertson, B.Sc., Ph.D.
Senior Research Officer—H. S. McKee, B.A., D.Phil.
Research Officer—Miss M. Wilkins, M.Sc.
Research Officer—Miss J. Fraser, M.Sc.
Technical Officer—Miss G. Bruck, B.Sc.
Technical Officer—Mrs. L. Nesztel, B.Sc.

At Biochemistry School, University of Sydney—

Physical Chemistry Section—

Research Officer—H. A. McKenzie, M.Sc.
Technical Officer—Miss M. Ryan, B.Sc.

At Botany School, University of Melbourne—
Microbiology Section—

Research Officer—B. T. Overell, M.Sc.

At Brisbane—
Meat Investigations—

Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr.Ing.
Research Officer—A. D. Brown, B.Sc.
Technical Officer—N. T. Russell, D.I.C.
Technical Officer—P. E. Bouton, B.Sc.

At Africa House, London—

Senior Research Officer—N. E. Holmes, B.E.E., M.Mech.E. (seconded).

15. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—

Chief—S. A. Clarke, B.E.
Assistant to Chief—C. S. Elliott, B.Sc.
Assistant to Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Information Officer—A. P. Wymond, M.Sc.
Librarian—Miss M. I. Hulme.
Assistant to Librarian—Miss A. Forbes.
Senior Technical Officer—L. Santer, Dip.Eng.
Publications Officer—Miss J. Cameron.

Wood Structure Section—

Senior Principal Research Officer-in-charge—H. E. Dadswell, D.Sc.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Senior Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Research Officer—I. J. W. Bisset, B.Sc.
Research Officer—G. L. Amos, M.Sc.
Technical Officer—Miss M. F. Day, B.Sc.

Photography—

Technical Officer—W. G. Hastie.
Technical Officer—Miss Audrey M. Lightfoot.

Chemistry Section—

Senior Principal Research Officer-in-charge—W. E. Cohen, D.Sc.
Senior Research Officer—D. E. Bland, M.Sc.
Research Officer—D. H. Foster, M.Sc.
Research Officer—W. E. Hillis, M.Sc., A.G.Inst.Tech.
Research Officer—A. von Koeppen, Dr.Ing.
Research Officer—R. C. McK. Stewart, B.Sc.
Research Officer—A. J. Watson, A.M.T.C.
Technical Officer—A. G. Charles.
Technical Officer—Miss M. F. Gatley, B.Sc.
Technical Officer—J. A. McPherson, B.Sc.
Technical Officer—Miss G. Schwerin, B.Sc.

Timber Physics Section—

Senior Research Officer-in-charge—R. S. T. Kingston, B.Sc., B.E.
Research Officer—L. N. Clarke, B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, B.Sc.
Technical Officer—A. Ack Hing, A.S.M.B.
Technical Officer—L. D. Armstrong.
Technical Officer—N. C. Edwards, A.S.M.B.
Technical Officer—P. U. A. Grossman, Ph.A.Mr.
Technical Officer—J. W. P. Nicholls, B.Sc.
Technical Officer—I. G. Scott, B.Sc., F.M.T.C.

Timber Mechanics Section—

Principal Research Officer-in-charge—K. L. Cooper, M.A., B.Sc.
Senior Research Officer—J. D. Boyd, M.C.E.
Research Officer—N. H. Kloot, B.Sc.
Research Officer—R. G. Pearson, B.A., B.C.E.
Technical Officer—Miss E. A. Blair, B.Sc.
Technical Officer—J. J. Mack.

Timber Seasoning Section—

Principal Research Officer-in-charge—G. W. Wright, M.E.
Senior Research Officer—J. W. Gottstein, B.Sc.
Research Officer—E. L. Ellwood, M.Sc. (For.).
Research Officer—M. Grumach, B.Sc.
Technical Officer—L. J. Brennan.
Technical Officer—G. S. Campbell.
Technical Officer—H. D. Roberts.

Timber Preservation Section—

Principal Research Officer-in-charge—N. Tamblyn, M.Sc.(Agric.).
Research Officer—G. N. Christensen, M.Sc.
Research Officer—E. W. B. da Costa, M.Agr.Sc.
Research Officer—Miss N. E. Kent, B.Sc.
Research Officer—G. W. Tack, B.Agr.Sc.
Senior Technical Officer—F. A. Dale, F.M.T.C.
Technical Officer—J. Beesley, B.Sc.(For.), Dip.For.
Technical Officer—Miss N. Robinson.
Technical Officer—A. Rosel.
Technical Officer—Miss S. J. Wilson, M.Sc.

Veneer and Gluing Section—

Senior Research Officer-in-charge—A. Gordon, B.Sc.
Research Officer—H. G. Higgins, B.Sc.
Research Officer—K. F. Plomley, B.Sc. (Agr.).
Technical Officer—Miss D. R. Fraser, B.Sc.
Technical Officer—Miss J. U. Barrie, A.M.T.C.
Technical Officer—K. Hirst.

Utilization Section—

Principal Research Officer-in-charge—R. F. Turnbull, B.E.
Technical Officer—S. J. Colwell, A.M.T.C.
Technical Officer—R. L. Cowling, Dip.Mech.Eng., Dip.E.E.
Technical Officer—W. M. McKenzie, B.Sc.(For.).

Maintenance Section—

Senior Technical Officer—S. G. McNeil.

16. Division of Industrial Chemistry.

(Head-quarters: Lorimer-street, Fishermen's Bend, Melbourne.)

Administration—

Chief—I. W. Wark, D.Sc., Ph.D.
Divisional Secretary—L. Lewis, B.Met.E.
Assistant Secretary—A. E. Scott, M.Sc.

Minerals Utilization Section—

Senior Principal Research Officer—R. G. Thomas, B.Sc.
Senior Research Officer—T. R. Scott, D.Sc., B.Ed.
Senior Research Officer—A. Walkley, B.A., D.Sc., Ph.D.
Senior Research Officer—A. W. Wylie, M.Sc., Ph.D.
Research Officer—J. N. Almond, M.Sc.
Research Officer—R. C. Croft, M.Sc.
Research Officer—P. Dixon, M.Sc.
Research Officer—P. M. J. Gray, B.Sc., A.R.S.M.
Research Officer—J. H. Green, M.Sc., Ph.D.
Research Officer—F. R. Hartley, M.Sc.
Research Officer—J. D. Hayton, B.Sc. (at S.A. School of Mines, Adelaide).
Research Officer—I. E. Newnham, M.Sc.
Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—R. C. Vickery, M.Sc., Ph.D.
Research Officer—A. D. Wadsley, M.Sc.
Senior Technical Officer—H. R. Skewes.

Cement and Ceramics Section—

Senior Principal Research Officer—A. R. Alderman, D.Sc., Ph.D.
Principal Research Officer—G. F. Walker, B.Sc., Ph.D.
Principal Research Officer—W. O. Williamson, B.Sc., Ph.D.
Senior Research Officer—H. E. Vivian, B.Sc.Agr.
Part-time Officer—A. J. Gaskin, M.Sc.
Research Officer—K. M. Alexander, M.Sc., Ph.D.
Research Officer—S. M. Brisbane, B.A., A.M.T.C.
Research Officer—G. M. Bruere, M.Sc.
Research Officer—C. E. S. Davis, B.Sc.
Research Officer—H. Ellerton (at Bonython Research Laboratory, S.A. School of Mines, Adelaide).
Research Officer—H. R. Samson, M.Sc. (on study leave).
Research Officer—E. R. Segnit, M.Sc., Ph.D.
Technical Officer—I. C. Bennett, A.M.T.C.
Technical Officer—R. W. Cox, F.M.T.C.
Technical Officer—J. Coutts, A.M.T.C.
Technical Officer—R. R. Hughan.
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. H. Weymouth, B.Sc.
Technical Officer—J. D. Wolfe.

Foundry Sands Section—

Senior Research Officer—H. A. Stephens, B.Sc.
Technical Officer—P. W. Goad, A.M.T.C.
Technical Officer—A. N. Waterworth, A.H.T.C.

Chemical Physics Section—

Senior Principal Research Officer—A. L. G. Rees, D.Sc., Ph.D.
Senior Research Officer—A. Walsh, M.Sc.Tech.
Senior Research Officer—E. H. Mercer, B.Sc., Ph.D.
Senior Research Officer—J. L. Farrant, M.Sc.
Senior Research Officer—A. McL. Mathieson, B.Sc., Ph.D.
Senior Research Officer—D. A. Davies, B.Sc.
Research Officer—J. M. Cowley, M.Sc., Ph.D.
Research Officer—J. D. Morrison, B.Sc., Ph.D.
Research Officer—J. B. Willis, M.Sc., Ph.D.
Research Officer—A. F. Moodie, B.Sc.
Research Officer—C. Billington, B.A.
Research Officer—B. Dawson, M.Sc., Ph.D.
Research Officer—J. P. Shelton, M.Sc., A.B.S.M.
Research Officer—A. J. Hodge, B.Sc. (on study leave).
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia, Perth).
Research Officer—N. S. Ham, M.Sc.
Research Officer—P. Goodman, M.Sc.
Research Officer—J. Fridrichsons, M.Sc.
Research Officer—J. C. Riviere, M.Sc.
Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Research Officer—A. F. Beecham, B.Sc.
Senior Technical Officer—W. G. Jones.
Technical Officer—S. E. Powell.
Technical Officer—Miss R. J. Beckett, B.Sc.
Technical Officer—G. F. H. Box.
Technical Officer—F. B. Williams.
Draughtsman—N. McVilly.
Draughtsman—M. F. Morgan.

Physical Chemistry Section—

Principal Research Officer—K. L. Sutherland, D.Sc., Ph.D.
Research Officer—W. E. Ewers, M.Sc.
Research Officer—W. W. Mansfield, B.Sc.
Research Officer—J. B. Reed, B.Sc., Ph.D.
Research Officer—M. E. Winfield, M.Sc., Ph.D.
Technical Officer—L. F. Evans, D.S.M.B.

Organic Chemistry Section—

Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Principal Research Officer—J. R. Price, M.Sc., D.Phil.
Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D.
Senior Research Officer—W. Zimmermann, D.Ing.
Research Officer—C. S. Barnes, M.Sc.
Research Officer—R. B. Bradbury, B.Sc.Agr., D.B.S.M. (at University of W.A., Perth).
Research Officer—W. D. Crow, M.Sc. (on stndy leave).
Research Officer—C. C. J. Culvenor, Ph.D., D.Phil.
Research Officer—R. G. Curtis, M.Sc., D.I.C.
Research Officer—L. K. Dalton, A.S.T.C.
Research Officer—H. Duewell, B.Sc., Ph.D.
Research Officer—N. C. Hancox, M.Sc.
Research Officer—R. J. L. Martin, M.Sc., Ph.D.
Research Officer—K. E. Murray, B.Sc.
Research Officer—N. V. Riggs, B.Sc., Ph.D.
Research Officer—H. Silberman, Ph.D. (at Sydney).
Technical Officer—A. W. McKenzie, A.M.T.C.
Technical Officer—A. H. Redcliffe, D.A.C.
Technical Officer—Miss E. E. Rutherford, B.Sc.
Technical Officer—R. Schoenfeld, B.Sc.

Chemical Engineering Section—

Principal Research Officer—D. R. Zeidler, M.Sc.
Senior Research Officer—R. W. Urie, B.Sc., S.M.
Research Officer—J. A. Barker, B.A., B.Sc.
Research Officer—D. Barrett, M.Sc.
Research Officer—T. J. Birch, B.Sc.
Research Officer—I. Brown, B.Sc.
Research Officer—K. E. Calderbank, M.Sc.
Research Officer—H. G. David, B.Sc. (at Department of Chemical Engineering, Sydney University).
Research Officer—A. Ewald, B.Sc. (on study leave).
Research Officer—K. R. Hall, B.Sc.
Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Department of Chemical Engineering, Sydney University).
Research Officer—O. G. Ingles, M.Sc.
Research Officer—J. F. Pearse, B.Sc., Ph.D., D.I.C. (at Department of Chemical Engineering, Sydney University).
Research Officer—J. B. Ross, B.Sc., A.M.T.C.
Research Officer—E. M. Rossiter, B.Sc.
Research Officer—E. A. Swinton, B.Sc.
Research Officer—P. Terry, B.Sc.
Research Officer—D. E. Weiss, B.Sc.
Research Officer—B. W. Wilson, M.Sc.
Technical Officer—J. L. Clay, A.M.T.C.
Technical Officer—K. W. Foley, B.Sc.
Technical Officer—K. F. Drinan, B.Sc.
Technical Officer—E. M. Jenkins, A.M.T.C.
Technical Officer—M. Linton, B.Sc.
Technical Officer—Miss P. C. Miller, B.A.
Technical Officer—M. Ross, Ing.
Technical Officer—E. F. Symons, A.M.T.C.
Technical Officer—D. H. Trethewey, A.M.T.C.
Draughtsman—J. Hession.
Draughtsman—J. R. Pendlebury.
Draughtsman—C. Simpson.

At University of Western Australia—
Alunite Investigations—

Research Officer—D. F. A. Koch, B.Sc.

At Canberra, Division of Entomology—

Research Officer—R. H. Hackman, M.Sc., Ph.D. (seconded).

At Canberra, Division of Plant Industry—
Research Officer—W. Bottomley, M.Sc. (seconded).
At Sydney, Division of Electrotechnology—
Senior Research Officer—R. J. Meakins, B.Sc., Ph.D. (seconded).
Research Officer—Miss J. W. Mulley, A.S.T.C. (seconded).
Research Officer—H. K. Welsh, B.Sc. (seconded).
Photography—
Technical Officer—F. D. Lugton.
Library—
Librarian—Miss B. M. Brown, B.Sc.

17. Irrigation Research Station
(Murrumbidgee Irrigation Areas).
(Head-quarters: Griffith, New South Wales.)
Officer-in-charge—E. S. West, B.Sc., M.S.
Senior Research Officer (plant physiology)—R. F. Williams, M.Sc.
Senior Research Officer (chemistry)—L. A. Whelan, M.Sc., Ph.D.
Research Officer (irrigation)—O. Perkman, B.Sc.Agr.
Research Officer (drainage)—V. J. Wagner, B.Sc.Agr.
Research Officer (vegetable agronomy)—K. Spencer, B.Sc.Agr.
Research Officer (soil physics)—E. L. Greacen, B.Sc.Agr., Ph.D.
Research Officer (horticulture)—H. J. Frith, B.Sc.Agr.
Research Officer (plant physiology)—C. T. Gates, B.Sc.Agr.
Senior Technical Officer (orchard superintendent)—B. H. Martin, H. D. A.
Technical Officer (chemistry)—G. Sosnovsky, Ph.D.
Technical Officer (photography)—A. N. Huon.
Technical Officer (chemistry)—Miss J. Connor, B.Sc.
Librarian—Miss M. Russell.
Seconded to New South Wales Department of Agriculture—
Senior Research Officer—D. V. Walters, M.Agr.Sc.
Research Officer—Mrs. J. Tully, B.Sc., Ph.D.

18. Land Research and Regional Survey Section.
(Head-quarters: Canberra, Australian Capital Territory.)
At Head-quarters, Canberra—
Officer-in-charge—C. S. Christian, B.Sc.Agr., M.S.
Research Officer—Miss M. Mills, B.Sc.
Research Officer—R. O. Slatyer, B.Sc. (Agric.).
At Ayr, Queensland—
Research Officer—F. H. Kleinschmidt, B.Sc.Agr.
At Kimberley Research Station, Western Australia—
Research Officer—L. C. Lee, B.Agr.Sc.
Technical Officer—E. C. B. Langfield.
At Katherine Research Station, Northern Territory—
Research Officer—W. Arndt, B.Agr.Sc.
Technical Officer—L. J. Phillips, Q.D.D.M.
Regional Survey, Canberra—
Research Officer—G. A. Stewart, B.Agr.Sc. (seconded from Division of Soils).
Research Officer—R. A. Perry, B.Sc.
Research Officer—S. J. Paterson, B.Sc.
Technical Officer—N. Lazarides, Q.D.A.

19. Section of Mathematical Instruments.
(Head-quarters: University of Sydney.)
Officer-in-charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.
Senior Research Officer—W. R. Blunden, B.Sc., B.E.
Research Officer—M. W. Allen, B.E.
Research Officer—C. B. Speedy, B. E. (attached from University of Sydney).
Technical Officer—R. J. Keith, A.S.T.C.
Technical Officer—K. F. Sayers.
Technical Officer—B. Z. de Ferranti, B.Sc., B.E.

20. Section of Mathematical Statistics.
(Head-quarters: University of Adelaide.)
At Head-quarters, Adelaide—
Officer-in-charge—E. A. Cornish, D.Sc., B.Agr.Sc.
Research Officer—Miss E. A. Adam, B.A.
Research Officer—K. P. Haydock, B.Sc.
Research Officer—A. T. James, M.Sc. (abroad).
Research Officer—P. F. May, B.Sc.Agr.
Research Officer—K. W. Morris, B.Sc.
Research Officer—G. N. Wilkinson, B.Sc.
Sectional Secretary—Miss E. M. G. Goodale.
At Division of Animal Health and Production, Sydney—
Senior Research Officer—Miss H. A. Newton Turner, B.Arch.
Research Officer—Miss M. C. McKevett, B.A.
Research Officer—Mrs. E. F. Turton, B.Sc.
At Division of Building Research, Highett, Victoria—
Research Officer—R. Birtwistle, B.Sc.
At Division of Food Preservation and Transport, Homebush, New South Wales—
Research Officer—G. G. Coote, B.A., B.Sc.
At Division of Forest Products, Melbourne—
Senior Research Officer—E. J. Williams, B.Com.
Technical Officer—Miss N. Ditchburne.
At Division of Plant Industry, Canberra—
Senior Research Officer—G. A. McIntyre, B.Sc., Dip.Ed.
Research Officer—Miss N. B. Hemingway, B.Sc.
At University of Western Australia, Perth—
Research Officer—N. S. Stenhouse, B.Sc.

21. Section of Meteorological Physics.
(Head-quarters: Graham-road, Highett, Victoria.)
Officer-in-charge—C. H. B. Priestley, M.A.
Principal Research Officer—W. C. Swinbank, B.Sc.
Senior Research Officer—E. L. Deacon, B.Sc.
Senior Research Officer—R. W. James, M.Sc.
Senior Research Officer—J. W. Hutchings, B.A., M.Sc.
Research Officer—I. C. McIlroy, B.Sc.
Research Officer—E. K. Webb, B.A., B.Sc.
Research Officer—F. K. Ball, B.Sc.
Senior Technical Officer—R. J. Taylor, B.Sc.
Technical Officer—I. S. Groodin, Dip.Mat.
Technical Officer—D. E. Angus, B.Sc.
Technical Officer—A. J. Troup, B.Sc.
Technical Officer—Mrs. R. I. Lee.

22. Division of Metrology.
(Head-quarters: National Standards Laboratory at University of Sydney.)
Chief—N. A. Esserman, B.Sc.
Technical Secretary—N. H. Winters, B.E.
Principal Research Officer—C. A. Gladman, B.Sc.
Senior Research Officer—P. M. Gilet, B.Sc., B.E.
Senior Research Officer—G. A. Bell, B.Sc.
Senior Research Officer—H. J. Ritter, Dr.rer.nat.-math.
Senior Research Officer—C. F. Bruce, M.Sc.
Research Officer—H. A. Ross, A.S.T.C.
Research Officer—R. H. Furniss, A.S.T.C.
Research Officer—J. A. Macinante, B.E., A.S.T.C.
Research Officer—W. A. F. Cuninghame, B.E.
Research Officer—Miss M. C. Dive, B.Sc.
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—Miss P. M. Yelland.

Research Officer—R. J. Ellis, B.E.
Research Officer—Miss M. M. Douglas, B.Sc.
Research Officer—J. R. Waldersee, B.Sc.
Research Officer—V. R. Findlay, M.Sc.
Research Officer—N. J. C. Peres, B.Sc.
Technical Officer—D. H. Fox.
Technical Officer—G. W. Gore, A.S.T.C.
Technical Officer—J. W. Bell.
Technical Officer—R. J. Hemphill.
Technical Officer—E. Grunwald.
Technical Officer—J. C. Kelly, B.Sc.
Technical Officer—E. J. Thwaite, B.Sc.
Technical Officer—I. F. Mayer, B.Sc.
Technical Officer—I. J. Somervaille, A.S.T.C.
Technical Officer—S. A. Dunk, A.S.T.C.
Technical Officer—O. Pain.

23. Mineragraphic Investigations.

(Head-quarters: University of Melbourne.)

Senior Principal Research Officer—F. L. Stillwell, D.Sc.
Principal Research Officer—A. B. Edwards, D.Sc., Ph.D.
Research Officer—G. Baker, M.Sc.
Technical Officer—G. C. Carlos.

24. National Standards Laboratory.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory.)

Clerical—

Chief Clerk—W. J. Gillespie, A.F.I.A., A.C.I.S.

Drawing Office—

Chief Draughtsman—C. M. Williamson.

Library—

Librarian—Miss M. McKechnie, B.A.
Librarian—Miss J. M. Cook, B.A.
Librarian—Miss P. Feughelman, B.A.
Assistant Librarian—Miss A. Benardos.

Workshops—

Engineer-in-charge—J. Hanna.

25. Oenological Research.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Senior Research Officer—J. C. M. Fornachon, M.Sc., B.Ag.Sc.
Research Officer—B. C. Rankine, B.Sc.

26. Ore-dressing Investigations.

At University of Melbourne—

Officer-in-charge—Associate-Professor H. H. Dunkin, B.Met.E.
Senior Research Officer—K. S. Blaskett, B.E.
Research Officer—S. B. Hudson, M.Sc.
Research Officer—J. T. Woodcock, B.Met.E., M.Eng.Sc.
Technical Officer—F. D. Drews.
Technical Officer—R. R. Laver.
Technical Officer—T. F. Wallace.

27. Section of Physical Metallurgy.

(Head-quarters: University of Melbourne.)

Officer-in-charge (honorary)—Professor J. Neill Greenwood, D.Sc., M.Met.E.
Senior Research Officer—H. W. Worner, M.Sc.
Research Officer—R. C. Gifkins, B.Sc.
Research Officer—A. E. Jenkins, M.Eng.Sc.
Technical Officer—J. A. Corbett.
Technical Officer—G. Boyd, A.M.T.C.

28. Division of Physics.

Administration—

Chief—G. H. Briggs, D.Sc., Ph.D.
Technical Secretary—D. S. Woodward.

Heat—

Principal Research Officer—A. F. A. Harper, M.Sc.
Research Officer—W. R. G. Kemp, B.Sc.
Research Officer—R. G. Wylie, M.Sc.
Research Officer—G. K. White, M.Sc., D.Phil.
Research Officer—P. G. Klemens, M.Sc., D.Phil.
Research Officer—W. A. Caw, B.Sc.
Research Officer—Miss R. Scott, B.Sc.
Research Officer—N. H. Westwood, B.Sc.
Research Officer—A. J. Mortlock, B.Sc.
Research Officer—J. Middlehurst, B.Sc.
Technical Officer—J. K. Braithwaite, A.M.T.C.
Technical Officer—J. W. W. Smyth.

Light—

Principal Research Officer—R. G. Giovanelli, D.Sc.
Research Officer—W. H. Steel, B.A., B.Sc. (abroad).
Research Officer—K. A. Wright, B.Sc.
Research Officer—M. Kossenberg, Ph.D.
Research Officer—R. J. Le Mesurier, B.Sc.
Research Officer—G. H. Godfrey, M.A., B.Sc. (part-time).
Technical Officer—W. J. Brown, A.S.T.C.
Technical Officer—D. G. Norton.

Solar Physics—

Research Officer—J. T. Jefferies, B.Sc.

Electronics—

Research Officer—A. F. Young, M.Sc.

Technical Services—

Technical Officer—J. E. Thompson.

29. Division of Plant Industry.

(Head-quarters: Canberra, Australian Capital Territory.)

At Canberra—

Administration and General—

Acting Chief—J. G. Davies, B.Sc., Ph.D.
Technical Secretary—A. Shavitsky, B.Agr.Sc.
Senior Clerical Officer—K. J. Prowse.
Accountant—D. W. Banyard.
Technical Officer (photographer)—J. B. Pomeroy.
Technical Officer (workshop)—C. H. Wilson.
Librarian—Miss J. Humphreys, B.A., Dip.Ed.
Assistant Librarian—Miss M. Campbell-Smith.

Disease Control Studies—

Principal Research Officer—H. R. Angell, O.B.E., Ph.D.
Technical Officer—P. K. Macnicol.

Microbiology—

Senior Research Officer—D. O. Norris, D.Sc. (Agric.).
Senior Research Officer—W. V. Ludbrook, M.S., B.Agr.Sc., Ph.D.
Research Officer—J. H. E. Mackay, B.Sc.Agr.
Research Officer—Miss K. Helms, B.Sc.
Technical Officer—J. Brockwell, D.D.A.
Technical Officer—Miss J. N. Friend, B.Sc.Agr.

Plant Introduction—

Principal Research Officer—W. Hartley, B.A., Dip.Agr.
Research Officer—C. A. Neal-Smith, B.Agr.Sc., R.D.A.
Technical Officer—R. Seton.
Technical Officer—R. J. Williams, B.Sc.
Technical Officer—Miss D. E. Johns, B.Sc.

Herbarium—

Research Officer—Miss N. T. Burbidge, M.Sc.

Horticultural Investigations—

Principal Research Officer—C. Barnard, D.Sc.

Medicinal and Drug Plant Investigations—

Senior Research Officer—K. L. Hills, M.Agr.Sc.
Research Officer—W. Bottomley, B.Sc., Ph.D.
Technical Officer—D. R. Meyer.
Technical Officer—P. I. Mortimer, B.Sc.

Plant Physiology—

Senior Research Officer—R. F. Williams, M.Sc. (seconded to Irrigation Research Station, Griffith).
Research Officer—J. Calvert, D.Sc.

Agrostology—

Acting Chief of the Division—J. G. Davies, B.Sc., Ph.D.
Principal Research Officer—C. M. Donald, M.Agr.Sc. (abroad).
Research Officer—E. F. Biddiscombe, B.Sc. (Agric.).
Technical Officer—J. Deans.
Technical Officer—L. Lazarides, Q.D.A.
Technical Officer—V. H. Southwell, Dip.Eng.
Technical Officer—A. Axelsen, Q.D.A.H.

Agrostology, Pasture Ecology—

Research Officer—C. W. E. Moore, B.Agr.Sc.

Agrostology, Weeds Ecology—

Senior Research Officer—R. M. Moore, B.Sc.Agr.
Research Officer—L. F. Myers, B.Agr.Sc.
Technical Officer—C. S. McKay, Dip.Agr.D.
Technical Officer—R. T. Milligan, Dip.Agr.D.
Technical Officer—J. A. Robertson, Q.D.D.M.

Agrostology, Mineral Deficiency Studies—

Senior Research Officer—A. J. Anderson, B.Sc. (Agric.).
Research Officer—D. Spencer, B.Sc. (on study leave).
Research Officer—K. D. McLachlan, B.Sc.Agr., B.Comm.
Technical Officer—D. Moye, H.D.A.
Technical Officer—R. G. Fawcett, R.D.A.

Agrostology, Plant Toxicology—

Senior Research Officer—C. G. Greenham, M.Sc.
Research Officer—P. Goldacre, B.Sc.
Technical Officer—C. V. de Plater, A.I.M.R.E.

Agrostology, Pasture Chemistry—

Senior Research Officer—C. H. Williams, M.Sc.
Research Officer—A. Steinbergs.
Research Officer—D. J. David, B.Sc.
Technical Officer—F. K. Mayer, Q.D.A.

Tobacco Investigations—

Principal Research Officer—A. V. Hill, M.Agr.Sc.
Research Officer—R. Johanson, M.Sc.
Technical Officer—M. Mandryk, B.Sc.Agr.
Technical Officer—Mrs. D. Encel, B.Sc.

Plant Genetics—

Senior Research Officer—E. M. Hutton, D.Sc., B.Agr.Sc.
Research Officer—D. C. Wark, M.Agr.Sc.
Research Officer—R. D. Brock, B.Agr.Sc.
Technical Officer—A. R. Peak, H.D.A.
Technical Officer—R. R. Rochford.
Technical Officer—J. W. Peak.
Technical Officer—J. D. Williams, D.D.A.

At Dickson Experiment Station, Canberra, Australian Capital Territory—

Senior Research Officer (agrostology)—W. D. Andrew, M.Agr.Sc.
Research Officer (agrostology) — W. M. Willoughby, B.Sc.Agr.
Farm Manager—L. Sharp, Dip.Agr.D.
Technical Officer—J. A. Redpath.

At Plant and Soils Laboratory, Queensland—

Principal Research Officer (agrostology)—T. B. Paltridge, B.Sc.
Senior Research Officer (plant introduction)—J. F. Miles, B.Agr.Sc.
Senior Research Officer (agrostology)—W. W. Bryan, M.Sc.Agr.
Research Officer (agrostology)—N. H. Shaw, B.Agr.Sc.
Research Officer (pasture chemistry)—E. H. Kipps, B.Sc.
Research Officer (native plant investigations)—L. J. Webb, M.Sc.
Research Officer (tobacco) — T. G. Haney, B.Sc.Agr.
Research Officer (agrostology)—Miss H. Barford, B.Sc.
Research Officer (agrostology)—J. E. Coaldrake, Dip.Agr.
Technical Officer (plant introduction)—R. B. Waite, Q.D.A.
Technical Officer—J. G. Tracey, Q.D.A.
Librarian—Miss B. Baird.

At Cooper Laboratory, Queensland Agricultural High School and College, Lawes—

Research Officer (agrostology)—W. G. Robertson, Q.D.A.
Research Officer (plant introduction) — S. G. Gray, B.Sc.Agr.
Research Officer (agrostology)—W. J. Bisset, B.Agr.Sc.
Technical Officer (plant introduction)—J. Conroy, Q.D.A.
Technical Officer (agrostology) — R. Milford, Q.D.A.
Technical Officer (agrostology)—G. J. Downing, Q.D.A.H.
Technical Officer (agrostology)—T. W. Elich, Dip.Col.Agr.
Technical Officer (agrostology)—W. H. J. Pieters, Dip.Col.Agr.
Technical Officer (agrostology) — H. Kiers, Dip.Col.Agr.
Technical Officer (agrostology)—G. A. Taylor.

At Stanthorpe, Queensland—

Senior Research Officer (horticultural investigations)—L. A. Thomas, M.Sc.
Research Officer (horticultural investigations)—R. C. Colbran, B.Agr.Sc.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—

Senior Research Officer (horticultural investigations)—L. A. Thomas, M.Sc.
Research Officer (horticultural investigations)—R. C. Colbran, B.Agr.Sc.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—

Principal Research Officer (agrostology)—R. W. Prunster, B.Sc.(Agric.).
Research Officer (agrostology) — N. Sinicins, Dip.Chem.Eng.
Research Officer (agrostology)—O. B. Williams, B.Agr.Sc.
Research Officer (agrostology)—K. P. J. Barley, B.Agr.Sc.
Technical Officer (agrostology)—G. J. Wright.
Technical Officer (agrostology)—J. W. Birch, Dip.Agr.D.
Technical Officer (agrostology)—F. Arndt, Q.D.A.

Clerical Officer—S. J. Cossar.
Manager, Falkiner Memorial Field Station—G. A. Vasey.

At the University of Western Australia, Perth, Western Australia—

Senior Research Officer (agrostology)—R. C. Rossiter, B.Sc.(Agric.).
Senior Research Officer (plant introduction)—E. T. Bailey, B.Sc.
Research Officer (agrostology)—P. G. Ozanne, B.Agr.Sc.
Technical Officer (agrostology)—R. J. Pack, Q.D.A.
Technical Officer (plant introduction)—N. B. Gayfer, Dip.Agr.D.
Technical Officer (agrostology)—J. Beresford, Dip.Agr.D.

At Kojonup, Western Australia—

Research Officer—E. R. Watson, B.Sc.(Agric.).
Station Manager—J. Tudor.

At Regional Pastoral Laboratory, Armidale, New South Wales—

Senior Research Officer (agrostology)—R. Roe, B.Sc. (Agric.).
Research Officer (agrostology)—E. J. Hilder, B.Sc.(Agric.).
Research Officer (ecology).—A. A. Holland, M.Sc.
Research Officer (ecology).—R. W. Jessup, M.Sc.
Research Officer (plant nutrition)—K. Spencer, B.Sc.(Agric.).
Technical Officer (chemistry)—J. R. Freney, B.Sc.
Technical Officer (agrostology)—P. B. Oelrichs, Q.D.A.
Technical Officer (agrostology)—V. J. Wolfe, Q.D.A.

At Hobart, Tasmania—

Senior Research Officer (horticultural investigations)—D. Martin, M.Sc.
Technical Officer—T. L. Lewis, B.Sc.
Technical Officer—J. Cerny, Ph.D.

At Mitchell Laboratory, Trangie, New South Wales—

Technical Officer (agrostology)—R. J. Hutchings, Dip.Agr.D.

At Waite Agricultural Research Institute, Adelaide, South Australia—

Principal Research Officer (physiology)—L. A. T. Ballard, Ph.D., M.Agr.S.
Research Officer (spectrographer)—D. J. David, B.Sc.
Technical Officer (gummosis)—L. G. Semmens, D.D.A.

At Ayr, Queensland—

Research Officer (tobacco)—W. J. Lovett, B.Agr.Sc.
Technical Officer (tobacco)—D. W. L. Simmons, D.D.A.
Technical Officer (tobacco)—J. S. Murday, Q.D.A.
Technical Officer (tobacco)—J. D. Fitzsimon, Q.D.A., Q.D.H.

At Katherine Research Station, Northern Territory—

Technical Officer (plant introduction)—A. E. Wynn.

30. Radio Research Board.

(Head-quarters: University of Sydney.)

At Canberra—

Senior Principal Research Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.Sc., F.R.S.
Research Officer—E. T. Robinson, B.Sc.
Technical Officer—R. O. Errey.

At Sydney—

Principal Research Officer—G. H. Munro, D.Sc.
Senior Research Officer—W. L. Price, B.Sc. (part-time).
Research Officer—J. A. Harvey, B.Sc.
Research Officer—L. Heisler, B.Sc.
Technical Officer—Miss B. Hardwick, B.A.
Technical Officer—H. P. Hirschl, A.S.T.C.
Technical Officer—R. B. White, B.E.

31. Division of Radiophysics.

(Head-quarters: University of Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.
Assistant Chief—J. L. Pawsey, M.Sc., Ph.D.
Technical Secretary—A. J. Higgs, B.Sc.

Radio Astronomy—

Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Senior Research Officer—W. N. Christiansen, M.Sc.
Senior Research Officer—H. C. Minnett, B.Sc., B.E.
Research Officer—Miss R. Payne-Scott, M.Sc.
Research Officer—J. G. Bolton, B.A.
Research Officer—R. N. Bracewell, B.Sc., B.E., Ph.D.
Research Officer—B. Y. Mills, B.Sc., M.E.
Research Officer—S. F. Smerd, B.Sc.
Research Officer—J. P. Wild, B.A.
Research Officer—C. A. Shain, B.Sc.
Research Officer—F. F. Gardner, B.Sc., B.E.
Research Officer—E. K. Bigg, M.Sc.
Research Officer—R. X. McGee, B.Sc.
Research Officer—R. D. Davies, B.Sc.
Technical Officer—C. S. Higgins.
Technical Officer—J. V. Hindman.
Technical Officer—K. R. McAlister, A.S.T.C.
Technical Officer—G. J. Stanley, A.S.T.C.
Technical Officer—J. D. Murray, B.Eng.Sc.
Technical Officer—O. B. Slee.
Technical Officer—A. G. Little, A.S.T.C.
Technical Officer—H. Harant, A.S.T.C.

Rain and Cloud Physics—

Senior Research Officer—J. Warner, B.Sc., B.E.
Senior Research Officer—E. J. Smith, M.B.E., B.Sc.(Eng.).
Senior Research Officer—P. Squires, M.A.
Research Officer—G. A. Day.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—R. S. Styles, B.Sc., B.E.
Research Officer—N. R. Labrum, B.Sc.
Research Officer—H. L. Humphries, B.Sc., B.E.
Research Officer—S. Twomey, M.Sc.
Research Officer—J. W. Telford, B.Sc.
Research Officer—K. H. Holywell, B.Sc.
Senior Technical Officer—G. T. Miles.
Technical Officer—T. D. Newnham.
Technical Officer—F. W. Campbell.
Technical Officer—L. F. Clague.
Technical Officer—K. J. Heffernan.
Technical Officer—K. A. Davidson.
Technical Officer—D. C. Dunn.
Technical Officer—R. C. Baker.
Technical Officer—C. F. Attwood.
Technical Officer—N. S. Thorndike.
Technical Officer—S. A. Pett.
Technical Officer—R. T. H. Bowles.

Mathematical Physics—

Senior Research Officer—T. Peareey, B.Sc.
Research Officer—Miss M. A. Adamson, B.A., Dip.Ed.
Research Officer—B. J. J. McHugh, B.Sc.

Electronic Computing—
Senior Research Officer—M. Beard, B.Sc., B.E.
Senior Research Officer—B. F. C. Cooper, B.Sc., B.E.
Research Officer—R. D. Ryan, B.Sc., B.E.
Research Officer—G. W. Hill, B.Sc.
Technical Officer—F. C. Tonking, A.S.T.C.
Technical Officer—J. Algie, A.S.T.C.
Technical Officer—L. Wade, A.S.T.C.

Engineering Development—
Senior Research Officer—L. L. McCready, B.Sc., B.E.

Radio Navigation—
Research Officer—J. G. Downes, B.Sc.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer—M. Strohfeldt, M.Sc.
Technical Officer—P. T. Hedges, A.S.T.C.
Technical Officer—K. V. Sheridan.

Test Room—
Senior Technical Officer—G. A. Wells, A.S.T.C.
Technical Officer—R. S. Joseph, A.S.T.C.
Technical Officer—O. C. Turner.

Vacuum Physics—
Technical Officer—F. C. James.

Officers Abroad—
Senior Research Officer—F. J. Kerr, M.Sc.
Research Officer—K. C. Westfold, M.A., B.Sc.
Research Officer—J. A. Roberts, M.Sc.
Research Officer—R. F. Mullaly, B.Sc.

Photographic—
Technical Officer—R. S. B. Millett.
Technical Officer—A. J. A. Tolliday.

Office and Publications—
Miss S. Atkinson, B.A.
Mrs. A. Purdy, B.Sc.

Engineering Services—
Chief Draughtsman—F. M. Carter.
Works Supervisor—H. Byers.

32. Division of Soils.

(Head-quarters: Waite Agricultural Research Institute, Adelaide, South Australia.)

At Adelaide—

Administration—
Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.
Technical Secretary—A. L. C. Davidson, B.Sc., Ph.D.

Soil Survey and Pedology—
Senior Principal Research Officer—C. G. Stephens, D.Sc.
Research Officer—K. H. Northcote, B.Ag.Sc.
Research Officer—G. Blackburn, B.Ag.Sc.
Research Officer—J. Loveday, B.Ag.Sc.
Research Officer—E. A. Jackson, B.Ag.Sc.
Research Officer—C. B. Wells, B.Ag.Sc.
Technical Officer—W. H. Litchfield, B.Sc.Agr.
Draughtsman—P. D. Hooper.
Draughtsman—M. C. Coulls.

Soil Physics and Mechanics—
Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Research Officer—G. D. Aitchison, B.E.
Research Officer—K. Norrish, M.Sc. (abroad).
Research Officer—J. P. Quirk, B.Sc.Agr. (abroad).
Research Officer—C. G. Gurr, B.Sc.
Research Officer—J. W. Holmes, B.Sc.
Research Officer—E. W. Radoslovich, B.Sc.
Research Officer—D. S. McIntyre, M.Sc.
Technical Officer—A. W. Palm.

Soil Chemistry—
Principal Chemist—C. S. Piper, D.Sc.
Senior Research Officer—A. C. Oertel, M.Sc.
Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M.
Research Officer—H. C. T. Stace, B.Sc.
Research Officer—B. M. Tucker, B.Sc.
Research Officer—R. S. Beckwith, B.Sc.
Research Officer—M. Raupach, B.Sc.
Technical Officer—A. D. Haldane, B.Sc.
Technical Officer—R. M. Tavender, A.S.A.S.M.
Technical Officer—A. R. P. Clarke, A.S.A.S.M.
Technical Officer—R. M. McKenzie, A.S.A.S.M.

Soil Microbiology—
Research Officer—J. R. Harris, M.Sc.

Oil Seeds Investigation—R. E. Shapter.

At Brisbane—

Soil Survey and Pedology—
Senior Research Officer—G. D. Hubble, B.Ag.Sc.
Research Officer—G. G. Beckmann, B.Sc.
Technical Officer—C. H. Thompson, Dip.Agr.

Soil Physics—
Research Officer—G. B. Stirk, B.Sc.

Soil Chemistry—
Research Officer—A. E. Martin, B.Sc.
Research Officer—J. E. Cox, B.Sc.Agr.
Technical Officer—R. Reeve, Dip.Ind.Chem.

At Canberra—

Soil Survey and Pedology—
Research Officer—R. Brewer, B.Sc.
Research Officer—G. A. Stewart, B.Ag.Sc. (seconded to Land Research and Regional Survey Section).
Research Officer—J. R. Sleeman, B.Ag.Sc.

At Deniliquin—

Soil Survey and Pedology—
Senior Research Officer—B. E. Butler, B.Agr.Sc. (abroad).

At Hobart—

Soil Survey and Pedology—
Research Officer—K. D. Nicolls, B.Sc., B.Ag.Sc.
Research Officer—G. M. Dimmock, B.Sc.

Soil Chemistry—
Technical Officer—A. M. Graley, B.Sc.

At Perth—

Soil Survey and Pedology—
Senior Research Officer—R. Smith, B.Ag.Sc.
Research Officer—L. W. Pym, B.Sc.
Research Officer—T. Poutsma, B.Sc.

Soil Chemistry—
Research Officer—A. G. Turton, B.Sc.

33. Division of Tribophysics.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, D.Ing., M.Sc.
Senior Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc., A.G.Inst. Tech.
Research Officer—E. B. Greenhill, M.Sc., Ph.D.
Research Officer—A. J. W. Moore, B.Sc., Ph.D. (on leave).
Research Officer—R. G. Vines, M.Sc.
Research Officer—J. K. Mackenzie, B.A., B.Sc., Ph.D.
Research Officer—J. S. Bowles, M.Sc.
Research Officer—M. E. Hargreaves, B.Met.E., Ph.D.
Research Officer—D. Michell, B.E.E.
Research Officer—M. J. Ridge, M.Sc.
Research Officer—G. W. West, B.Sc., B.E.E.
Research Officer—T. Broom, M.A.

Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc.
Research Officer—B. D. Cuming, M.Sc.
Research Officer—A. J. Davis, B.Eng.
Research Officer—J. F. Nicholas, B.A., B.Sc.
Research Officer—G. J. Ogilvie, B.Met.E., M.Eng.Sc. (abroad).
Research Officer—J. V. Sanders, B.Sc., Ph.D.
Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Research Officer—J. A. Spink, B.Sc.
Research Officer—I. C. Watt, M.Sc.
Research Officer—J. E. Young, Ph.D.
Technical Officer—H. W. Hutchinson.
Technical Officer—F. H. Hay.
Technical Officer—J. J. Batten.
Technical Officer—G. Brinson.
Technical Officer—R. W. Coventry, B.Sc.
Technical Officer—D. J. Norris.
Technical Officer—G. R. Perger, F.M.T.C.
Technical Officer—R. G. Sherwood, A.M.T.C.
Technical Officer—W. J. Tegart, A.M.T.C.
Part-time Officer—S. R. McDonald, B.Sc.

34. Wildlife Section.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-charge—F. N. Ratcliffe, B.A.
Research Officer—Miss M. Lazarus, B.Sc.
Research Officer—J. le G. Brereton, B.Sc.
Research Officer—B. V. Fennessy, B.Agr.Sc.
Research Officer—K. Myers, B.Sc.
Technical Officer—J. H. Calaby.

35. Wool Textile Research Laboratories.

Senior Officer-in-charge—F. G. Lennox, D.Sc.

At Wool Textile Research Laboratory, Melbourne—

Biochemistry Unit, 572 Flinders-lane, Melbourne—

Officer-in-charge—F. G. Lennox, D.Sc.
Laboratory Secretary—C. Garrow, Dip.Pub. Admin., A.F.I.A.
Senior Research Officer—H. Lindley, B.A., Ph.D.
Senior Research Officer—W. G. Crewther, M.Sc.
Research Officer—T. A. Pressley, B.Sc.
Research Officer—J. M. Gillespie, M.Sc.
Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Research Officer—S. J. Leach, B.Sc.Tech., Ph.D.
Research Officer—J. M. Swan, B.Sc., Ph.D.
Research Officer—E. F. Woods, M.Sc., A.M.T.C.
Research Officer—J. A. Friend, M.Sc., Ph.D.
Research Officer—I. J. O'Donnell, M.Sc.
Research Officer—D. H. Simmonds, M.Sc. (abroad).
Research Officer—G. E. Rogers, M.Sc.

Solvent Degreasing Investigations, Maribyrnong—

Principal Research Officer—E. J. Drake.
Draughtsman—E. E. Slade.

At Wool Textile Research Laboratory, Sydney—

Physics and Engineering Unit, Delhi-road, North Ryde—

Officer-in-charge—V. D. Burgmann, B.Sc., B.E.
Technical Secretary—I. J. W. Bissett, B.Sc.
Research Officer—Mrs. K. R. Makinson, B.A. (abroad).
Research Officer—I. M. Stuart, B.Sc.
Technical Officer—A. R. Haly, B.Sc.
Technical Officer—Miss J. C. Griffith, A.S.T.C.
Assistant Librarian—Miss E. E. Shoebridge, B.A.

Carbonizing Investigations, 17 Randle-street, Sydney—

Senior Research Officer—M. R. Freney, B.Sc.

At Wool Textile Research Laboratory, Geelong—

Officer-in-charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary and Textile Liaison Officer—N. A. Whiffen, F.S.T.C.
Senior Research Officer—D. L. C. Jackson, B.Sc.
Research Officer—N. K. Boardman, M.Sc.
Research Officer—K. Vallance, B.Sc.
Research Officer—D. S. Taylor, B.A., B.Sc.
Research Officer—C. H. Nicholls, B.Sc.
Research Officer—J. R. McPhee, B.Sc.
Technical Officer—J. F. Sinclair.
Technical Officer—Miss R. J. Hope, A.G.Inst. Tech.
Technical Officer—A. Gray, B.Sc. (abroad).
Technical Officer—G. C. West, Dipl.Text.Ind.
Assistant Librarian—Miss R. Andrews.

36. Plant and Animal Genetics.

At Adelaide—

Senior Research Officer—B. Horowitz, D.Agr.Sc.

At Sydney—

Research Officer—A. S. Fraser, M.Sc., Ph.D.

XXXIV. PUBLICATIONS.

The following papers have been published during the year:—

1. Division of Animal Health and Production.

Austin, C. R. (1950).—Fertilization of the rat egg. *Nature.* 166:407.

Austin, C. R. (1950).—The fecundity of the immature rat following induced superovulation. *J. Endocrin.* 6:293-301.

Beck, A. B. (1950).—Studies on the excretion of oestrogens by pregnant ewes. *Aust. J. Agric. Res.* 1: 322-37.

Bull, L. B., Vasey, A. J., *and* Gamble, L. C. (1951).—A study on the mechanics of hand-feeding a maintenance ration to sheep during periods of drought. *Aust. Vet. J.* 27:59-62.

Durie, P. H. (1951).—The paramphistomes (Trematoda) of Australian ruminants. I. Systematics. *Proc. Linn. Soc. N.S.W.* 76:41-8.

Fisher, S.,* *and* Gregory, T. S. (1951).—Studies on a serological test for the diagnosis of tuberculosis in cattle. *Aust. Vet. J.* 27:25-34.

Franklin, M. C. (1950).—Influence of diet on dental development in the sheep. C.S.I.R.O. Aust. Bull. No. 252.

Hardy, Margaret H. (1949).—The development of mouse hair *in vitro,* with some observations on pigmentation. *J. Anat., Lond.* 83:364-84.

Hardy, Margaret H. (1950).—The development *in vitro* of the mammary glands of the mouse. *J. Anat., Lond.* 84:388-93.

Hardy, Margaret H. (1951).—The development of pelage hairs and vibrissae from skin in tissue culture. *Ann. N.Y. Acad. Sci.* 53:546-61.

Johnstone, I. L. (1951).—Studies on lamb-marking dressings for the prevention of fly-strike. *Aust. Vet. J.* 27:53-8.

Johnstone, I. L., *and* Scott, Marion T. (1951).—Field trials on the prevention of body-strike in sheep by the use of DDT and BHC. *Aust. Vet. J.* 27: 79-82.

Keith, R. K. (1951).—The occurrence of *Ascaris vitulorum* Goeze 1782 in calves in Australia. *Aust. Vet. J.* 27:129.

Kelley, R. B. (1950).—Inheritance of skin folding (wrinkling) of sheep. *Aust. J. Agric. Res.* 1: 471-95.

Kelley, R. B. (1951).—Polledness in domestic animals with special reference to sheep. *Aust. Vet. J.* 27: 8-15.

* Commonwealth Serum Laboratories, Parkville, Victoria.

Lazarus, Marian, *and* Rogers, W. P. (1950).—Uptake of phenothiazine labelled with sulphur-35 by the tissues of nematode parasites and their hosts. *Nature.* 166: 647-9.

Lazarus, Marian, *and* Rogers, W. P. (1951).—The mode of action of phenothiazine as an anthelmintic. The uptake of 35S-labelled phenothiazine by the tissues of nematode parasites and their hosts. *Aust. J. Sci. Res.* B 4: 163-79.

Massey, V., *and* Rogers, W. P. (1950).—Effects of oxygen carriers and oxygen tensions on fluoracetate inhibition of citrate utilization. *Nature.* 166: 951.

Reid, R. L. (1950).—Studies on the carbohydrate metabolism of sheep. II. The uptake by the tissues of glucose and acetic acid from the peripheral circulation. *Aust. J. Agric. Res.* 1: 338-54.

Reid, R. L. (1951).—Studies on the carbohydrate metabolism of sheep. III. The blood glucose during insulin hypoglycaemia. IV. Hypoglycaemic signs and their relationship to blood glucose. *Aust. J. Agric. Res.* 2: 132-57.

Roberts, F. H. S., *and* Moule, G. R.* (1951).—A preliminary report on the value of DDT and BHC for the control of body-strike in sheep. *Aust. Vet. J.* 27: 35-9.

Roberts, F. H. S., O'Sullivan, P. J.,† *and* Riek, R. F. (1951).—The significance of faecal egg counts in the diagnosis of parasitic gastro-enteritis of cattle. *Aust. Vet. J.* 27: 16-18.

Scott, Marion T. (1950).—Observations on the bionomics of *Linognathus pedalis. Aust. J. Agric. Res.* 1: 465-70.

Skaller, F., *and* Grigg, G. W. (1950).—The effect of orally administered synthetic oestrogen (hexoestrol) on the male fowl. *Aust. J. Agric. Res.* 1: 496-516.

Southcott, W. H. (1951).—Suspected tetrachlorethylene poisoning of sheep. *Aust. Vet. J.* 27: 130-1.

Southcott, W. H. (1951).—The toxicity and anthelminthic efficiency of hexachlorethane in sheep. *Aust. Vet. J.* 27: 18-21.

Stewart, D. F. (1950).—Studies on resistance of sheep to infestation with *Haemonchus contortus* and *Trichostrongylus* spp. and on the immunological reactions of sheep exposed to infestation. I. The preparation of antigens for the complement fixation test and the reactivity of the biochemical fractions of *H. contortus.* II. The antibody response to infestation with *H. contortus. Aust. J. Agric. Res.* 1: 285-300, 301-21.

Stewart, D. F. (1950).—Studies on resistance of sheep to infestation with *Haemonchus contortus* and *Trichostrongylus* spp. and on the immunological reactions of sheep exposed to infestation. III. The antibody response to infestation with *Trichostrongylus* spp. IV. The antibody response to natural infestation in grazing sheep and the "self cure" phenomenon. *Aust. J. Agric. Res.* 1: 413-26, 427-39.

Stewart, D. F. (1951).—Circulating antibodies in rats resistant to *Nippostrongylus muris. Nature.* 167: 151.

Waterhouse, D. F.,‡ *and* Scott, Marion T. (1950).—Insectory tests with insecticides to protect sheep against body strike. *Aust. J. Agric. Res.* 1: 440-55.

Whitlock, H. V. (1950).—A technique for counting trematode eggs in sheep faeces. *J. Helminth.* 24: 47-52.

* Sheep Husbandry Branch, Queensland Department of Agriculture and Stock.

† Animal Health Station, Queensland Department of Agriculture and Stock, Yeerongpilly.

‡ Division of Entomology, C.S.I.R.O., Canberra, Australian Capital Territory.

Whitten, W. K. (1950).—Inactivation of gonadotrophins. III. Inactivation and modification of serum gonadotrophin by periodate ions. *Aust. J. Sci. Res.* B 3: 346-55.

Wilson, L. T. (1951).—Physical analysis of the fleece of sheep for biological purposes. I. Actual and apparent cross-sectional areas of a staple of fleece wool under lateral compression. II. Estimation of the number and mean diameter of wool fibres from a cast of their cross-section. *Aust. J. Agric. Res.* 2: 181-204.

Wilson, L. T., *and* Roberts, N. F. (1951).—Physical analysis of the fleece of sheep for biological purposes. III. A means of measurement of the fibre-length distribution of fleece wool. *Aust. J. Agric. Res.* 2: 205-19.

2. Atomic Physics.

Oddie, T. H., *and* Scott, R. K. (1950).—Results of uptake and excretion tests with radio-iodine. *Brit. J. Radiol.* 23: 348-54.

3. Division of Biochemistry and General Nutrition.

Gray, F. V., *and* Pilgrim, A. F. (1950).—Fermentation in the rumen of the sheep. *Nature.* 166: 478-9.

Gray, F. V., *and* Pilgrim, A. F. (1951).—Fermentation in the rumen of the sheep. II. The production of volatile fatty acids during the fermentation of wheaten hay and lucerne hay in the rumen. *J. Exp. Biol.* 28: 83-90.

Gray, F. V., Pilgrim, A. F., *and* Weller, R. A. (1951).—Fermentation in the rumen of the sheep. I. The production of volatile fatty acids and methane during the fermentation of wheaten hay and lucerne hay *in vitro* by microorganisms from the rumen. *J. Exp. Biol.* 28: 74-82.

Gray, F. V., Pilgrim, A. F., Rodda, H. J., *and* Weller, R. A. (1951).—Volatile fatty acids in the rumen of the sheep. *Nature.* 167: 954.

Jarrett, I. G., *and* Potter, B. J. (1950).—The metabolism of acetate in sheep after injection of phlorhizin. *Aust. J. Exp. Biol. Med. Sci.* 28: 595-602.

Jarrett, I. G., *and* Potter, B. J. (1950).—Metabolism of acetate and propionate in the ruminant. *Nature.* 166: 515-7.

Lee, H. J. (1950).—The occurrence and correction of cobalt and copper deficiency affecting sheep in South Australia. *Aust. Vet. J.* 26: 152-9.

Lee, H. J. (1951).—Cobalt and copper deficiencies affecting sheep in South Australia. I. Symptoms and distribution. *J. Dep. Agric. S.A.* 54: 475-90.

Lee, H. J. (1951).—Cobalt and copper deficiencies affecting sheep in South Australia. II. Practical control measures. *J. Dep. Agric. S.A.* 54: 527-32.

Marston, H. R. (1950).—Copper deficiency in ruminants. Copper metabolism. (Johns Hopkins Press: Baltimore.)

Quinlan-Watson, T.A.F. (1951).—Aldolase activity in zinc-deficient plants. *Nature.* 167: 1033-4.

Riceman, D. S. (1950).—Mineral deficiency and pasture establishment in the Coonalpyn Downs, South Australia. *J. Dep. Agric. S.A.* 54: 132-40.

4. Division of Building Research.

Blakey, F. A. (1950).—Discussion (Ultimate strength of reinforced concrete beams, by S. D. Lash *and* J. W. Brison). *J. Amer. Concr. Inst.* 22: 472-5-472-7.

Cole, W. F., Sorum, H.,* *and* Taylor, W. H.,* (1951).—Structures of the plagioclase felspars. I. *Acta Cryst.* 4: 20-9.

Hammill, S.A. (1950).—Cabinet for filing microfilm. *Information.* 4: 20.

Hammill, S. A., *and* McTaggart, R. C. (1950).—Guide to the library. *Information.* 4: 13-17.

* Cavendish Laboratory, Cambridge, England.

Holden, T. S. (1950).—Automatic timer for photographic darkrooms. *Aust. J. Instrum. Technol.* 6:114-16.

Muncey, R. W. (1950).—Use of three-dimensional models in room acoustics. *J. Acoust. Soc. Amer.* 22:510-11.

Taylor, W. H. (1951).—Sulphate-resistant concrete. *Construct. Rev.* 23:19-23.

5. Commonwealth Research Station (Murray Irrigation Areas).

Baldwin, J. G. (1950).—Soil survey of the Shire of Whittlesea, Victoria. *Proc. Roy. Soc. Vict.* (N.S.) 62:173-96.

Giles, J. E., *and* Alexander, D. McE. (1950).—Frequency of irrigation for tomato plants. *J. Aust. Inst. Agric. Sci.* 16:95-100.

Sauer, M. R. (1951).—Growth of orange shoots. *Aust. J. Agric. Res.* 2:105-17.

6. Dairy Research Section.

Conochie, J. (1950).—Weed taint in Australian dairy products. *Aust. J. Dairy Technol.* 5 (2): 43.

Kumetat, K. (1951).—A substitute for egg-white from skim milk. *Catering.* 9 (105): 6.

Loftus Hills, G. (1950).—Butter manufacture in Australia. *Nord. Mejeri Tidsskr.* 16 (4): 45.

Loftus Hills, G. (1950).—World milk distribution. *Aust. J. Dairy Technol.* 5 (4): 131.

7. Division of Electrotechnology.

Hamon, B. V. (1951).—Precise frequency and voltage control for a sine wave alternator set. *Aust. J. Appl. Sci.* 2:1-25.

Hamon, B. V., *and* Meakins, R. J. (1950).—Low frequency dielectric absorption in organic long-chain compounds due to the presence of traces of alcohol impurities. *Nature.* 164:29.

Richardson, R. C., *and* Warner, J. (1950).—Straight flight of aircraft equipped with radar-operated pilot's indicator. *Photogram. Engng.* 1950:544-9.

Ross, I. G., *and* Sack, R. A. (1950).—Solvent effects in dipole moment measurements. *Proc. Phys. Soc.* B 63:893.

8. Division of Entomology.

Calaby, J. H. (1951).—Adenosine triphosphate from insect muscle. *Arch. Biochem. Biophys.* 31:294.

Carne, P. B. (1950).—Morphology of the immature stages of *Aphodius howitti* Hope (Coleoptera, Scarabaeidae, Aphodiinae). *Proc. Linn. Soc. N.S.W.* 75:158-66.

Day, M. F. (1951).—Studies on the digestion of wool by insects. I. Microscopy of digestion of wool by clothes moth larvae (*Tineola bisselliella* Humm.). *Aust. J. Sci. Res.* B 4:42-8.

Day, M. F. (1951).—Studies on the digestion of wool by insects. III. A comparison between the tracheation of the midgut of *Tineola* larvae and that of other insect tissues. *Aust. J. Sci. Res.* B 4:64-74.

Day, M. F. (1951).—The mechanism of secretion by the salivary gland of the cockroach *Periplaneta americana* L. *Aust. J. Sci. Res.* B 4:136-43.

Day, M. F., *and* McKinnon, Anne (1951).—A study of some aspects of the feeding of the jassid *Orosius*. *Aust. J. Sci. Res.* B 4:125-35.

Grylls, N. E. (1950).—Low-volume DDT spray treatment of a lucerne seed crop. *J. Aust. Inst. Agric. Sci.* 16:154-7

Helson, G. A. H. (1949).—The potato moth, *Gnorimoschema operculella* (Zell.), and its control in Australia. C.S.I.R.O. Aust. Bull. No. 248.

Helson, G. A. H. (1951).—The transmission of witches' broom virus disease of lucerne by the common brown leaf-hopper, *Orosius argentatus* (Evans). *Aust. J. Sci. Res.* B 4:115-24.

Key, K. H. L. (1950).—Critique on the phase theory of locusts. *Quart. Rev. Biol.* 25:363-407.

Nicholson, A. J. (1951).—A simple method of disintegrating cells. *Nature.* 167:563-4.

Norris, K. R. (1950).—The aestivating eggs of the red-legged earth mite, *Halotydeus destructor* (Tucker). C.S.I.R.O. Aust. Bull. No. 253.

Paramonov, S. J. (1950).—Notes on Australian Diptera. I.-V. *Ann. Mag. Nat. Hist.* (12) 3:515-34.

Paramonov, S. J. (1950).—A new African species (Apioceridae). *J. Ent. Soc. S. Afr.* 13:103-5.

Powning, R. F. (1950).—The compatibility of DDT with nicotine and alkaline diluents in agricultural dusts. *Aust. J. Agric. Res.* 1:178-81.

Powning, R. F., Day, M. F., *and* Irzykiewicz, H. (1951).—Studies on the digestion of wool by insects. II. The properties of some insect proteinases. *Aust. J. Sci. Res.* B 4:49-63.

Waterhouse, D. F., *and* Scott, M. T. (1950).—Insectary tests with insecticides to protect sheep against body strike. *Aust. J. Agric. Res.* 1:440-55.

Waterhouse, D. F. (1951).—Connective tissue strands in blowfly larvae. *Aust. J. Sci.* 13:25-6.

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XXXV. FINANCE.

I. Expenditure.

	£	£	£
(*a*) Salaries and contingencies			229,800*
(*b*) Investigations—			
(i) Animal Health and Production Problems		296,614	
Less contributions from—			
Wool Industry Fund	1,690		
Wool Research Trust Account	93,306		
Commonwealth Bank	1,350		
Queensland Government	1,000		
Australian Dairy Produce Board	2,000		
Australian Meat Board	1,387		
Australian Wool Board (balance of old grants)	28		
Ian McMaster Bequest	732		
Alexander Fraser Memorial Fund	300		
Burdekin Bequest (drought feeding)	1,560		
Revenue Funds—			
Regional Pastoral Laboratory, Armidale	7,886		
Burdekin Bequest	2,076		
Poultry Breeding	3,510		
Vaccine	900		
Contagious Pleuro-pnuemonia	800		
Tooradin Field Station	500		
Parasitology—McMaster Laboratory	1,373		
Oestrus	1,455		
Toxaemic Jaundice—Barooga	800		
Toxaemic Jaundice—Parkville	788		
Mastitis	2,905		
McMaster Field Station	2,015		
Gilruth Plains Field Station	11,186		
Cobram Field Station	261		
		139,808	
			156,806
(ii) Biochemistry and General Nutrition Problems		68,803	
Less contributions from—			
Commonwealth Bank	450		
Wool Research Trust Account	18,040		
Australian Wool Board (balance of old grants)	434		
Nutrition Laboratory Revenue Fund	653		
		19,577	
			49,226
(iii) Plant Problems—Division of Plant Industry		296,015	
Less contributions from—			
Department of National Development	5,324		
Western Australian Golf Association	24		
Wool Industry Fund	2,708		
Wool Research Trust Account	34,390		
Plant Industry Revenue Fund	1,070		
Cooper Laboratory Revenue Fund	290		
		43,806	
			252,209
(iv) Entomology Problems		96,683	
Less contributions from—			
Australian Meat Board	836		
		836	
			95,847
(v) Soils and Irrigation Problems of Irrigation Settlements—			
(*a*) Citricultural—Research Station, Griffith		52,149	
Less contributions from—			
New South Wales Water Conservation and Irrigation Commission	2,000		
Leeton Co-operative Canneries	100		
Griffith Research Station Revenue Fund	2,039		
		4,139	
			48,010
(*b*) Viticultural—Research Station, Merbein		33,361	
Less contributions from—			
Dried Fruits Control Board	1,201		
Mildura Co-operative Fruit Company	200		
Irymple Packing Company	200		
Red Cliffs Co-operative Fruit Company	200		
Aurora Packing Company	200		
Co-operative Dried Fruit Sales Limited	200		
Merbein Station Revenue	4,689		
		6,890	
			26,471

* The main items of expenditure under this heading are salaries of the Administrative Staff at the Organization's Head Office; salaries and expenses of officers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office Staff; and printing and general office expenditure.

	£	£	£
(vi) Soil Problems	..	74,637	
Less contributions from—			
Commonwealth Bank	1,000		
		1,000	
			73,637
Unapportioned overseas expenditure on Soils and Irrigation Investigations	..	..	7,857
(vii) Food Preservation and Transport Problems	..	112,185	
Less contributions from—			
Commonwealth Bank	1,200		
New South Wales Department of Agriculture	1,416		
Metropolitan Meat Industry Commission	500		
Queensland Meat Industry Board	850		
Australian Meat Board	375		
Australian Egg Board	435		
Food Preservation Revenue Fund	135		
Batlow Packing Company	50		
		4,961	
			107,224
(viii) Forest Products Problems	..	170,686	
Less contributions from—			
Australian Paper Manufacturers Limited	500		
Associated Pulp and Paper Mills Limited	500		
Commonwealth Bank	1,000		
Forest Products Revenue Fund	98		
		2,098	
			168,588
(ix) Mining and Metallurgy	..	18,014	
Less contributions from—			
Australian Institute of Mining and Metallurgy	500		
		500	
			17,514
	..	22,949	
(x) Radio Research			
Less contributions from—			
Postmaster-General's Department	5,000		
Department of Army, Navy and Air	10,000		
		15,000	
			7,949
(xi) Research Services	..	69,819	
Less contributions from—			
Wool Research Trust Account	2,799		
		2,799	
			67,020
(xii) Industrial Chemistry	..	222,941	
Less contributions from—			
National Gas Association	690		
Cement and Concrete Association	1,500		
		2,100	
			220,841
(xiii) Fisheries Investigations	..	..	127,906
(xiv) Mathematical Statistics	..	..	24,099
(xv) National Standards Laboratory	..	..	203,677
(xvi) Tribophysics	..	..	45,252
(xvii) Building Research	..	..	101,618
(xviii) Flax Research	..	..	26,013
(xix) Radiophysics Research	..	..	188,708
(xx) Metallurgical Research	..	..	6,384
(xxi) Nuclear Energy Research	..	..	43,899
(xxii) Meteorological Physics	..	..	27,958
(xxiii) Dairy Research	..	..	17,290
(xxiv) Wool Textile Research	..	115,186	
Less contributions from—			
Wool Research Trust Account	104,535		
Wool Industry Fund	8,827		
		113,362	
			1,824
(xxv) Fuel Research	..	..	62,235
(xxvi) Wild Life Survey	..	13,188	
Less contributions from—			
George Aitken Pastoral Research Trust	500		
Wool Research Trust Account	3,927		
		4,427	
			8,761
(xxvii) Miscellaneous—			
(*a*) Biophysical Research	..	1,166	
(*b*) Oenological Research	..	3,109	
(*c*) Genetic Investigations	..	2,200	
(*d*) Various	..	8,293	
		14,768	
Less contributions from—			
Australian Wine Board	1,280		
Science and Industry Endowment Fund	39		
		1,319	
			13,449
(xxviii) Unforeseen and Urgent—			
Total of Item (*b*)—Investigations	..	..	2,258,272
(*c*) Grants—			
(i) Grant to Leather Research Association	..	5,000	
(ii) Overseas Research Studentships	..	28,844	
		33,844	
Less contributions from—			
Wool Research Trust Account	10,260		
Science and Industry Endowment Fund	2,049		
		12,309	
			21,535
Total Salaries and Contingencies, Investigations and Grants	..	..	2,509,607

2. Contributions and Donations.

The following statement shows the receipts and disbursements during the year 1950-51 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund" (formerly "The Specific Purposes Trust Account"):—

	Receipts 1950-51 and balances brought forward from 1949-50.	Expenditure 1950-51.
	£	£
Wool Industry Fund Account	90,284	82,609*
Commonwealth Bank (Animal Health and Production, Horticultural, Food Preservation and Transport, and Forest Products Investigations)	5,000	5,000
Australian Wool Board (Animal Health and Production Investigations—Sheep Research)	2,088	463
Australian Dairy Produce Board (Mastitis Investigations)	2,000	2,000
George Aitken Pastoral Research Trust (Animal Health and Production Investigations	500	..
Queensland Government Cattle Research (Animal Health and Production Investigations—Sheep Research)	1,000	1,000
Australian Meat Board (Toxaemic Jaundice Investigations, Barooga, New South Wales)	1,000	1,000
Australian Meat Board (Caseous Lymphadenitis Investigations—Animal Health and Production)	412	..
Australian Meat Board (Beef Cattle Research)	108	108A
Australian Meat Board (Bovine Pleuropneumonia Investigations)	333	310
Alexander Fraser Memorial Fund	300	300
C.P.P. Fairbairn (Animal Health and Production Investigations—Foot-rot Control)	30	..
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	964	964B
West Australian Golf Association (Plant Industry Investigations)	24	24
Department of National Development — Northern Australia Regional Survey (Division of Plant Industry)	6,268	4,796
Department of National Development — Kimberley Research Station	547	528
United Graziers' Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Entomology)	172	..
Australian Meat Board — Colloidal Dispersions, Investigations (Entomology)	1,600	836
Burdekin Bequest (Drought Feeding Investigations)	1,560	1,560
New South Wales Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station)	2,000	2,000
Murrumbidgee Irrigation Area Executive Committee Project Farm (Griffith Research Station)	100	100
Mildura Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	255	250C
Irymple Packing Co. (Dried Vine Fruits Investigations, Merbein)	255	205C
Red Cliffs Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	255	205C
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	255	205C
Co-op. Dried Fruits Sales Ltd. (Dried Vine Fruit Investigations, Merbein)	265	215D
Dried Fruits Control Board (Dried Fruits Investigations)	1,600	1,201
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	403	..
Australian Meat Board (Meat Investigations)	500	500E
Metropolitan Meat Industry Commissioner of New South Wales (Meat Investigations)	500	500
Queensland Meat Industry Board (Meat Investigations)	850	850
New South Wales Department of Agriculture (Food Investigations)	1,000	1,000
W. Angliss Ltd. (Division of Food Preservation and Transport)	38	1,000
L. Berger and Sons (Division of Food Preservation and Transport)	100	..
Batlow Packing House Co-op. Ltd. (Division of Food Preservation and Transport — Fruit Juice Investigations)	600	50
Various Contributors (Division of Food Preservation and Transport —Fruit Juice Investigations)	28	..
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	435	435
New South Wales Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport)	558	416
Australian Paper Manufacturers Ltd. (Paper Pulp Investigations)	500	500
Associated Pulp and Paper Mills Ltd. (Paper Pulp Investigations)	500	500
Sundry Contributors (Forest Products Investigations)	3,007	98
Miscellaneous Contributors (Division of Forest Products—Timber Seasoning Work)	10	..
Miscellaneous Contributors (Division of Forest Products—Veneer and Gluing Work)	8	..
Victorian Railways—High Pressure Test—Railway Sleepers (Division of Forest Products)	1,180	..
Australian Institute of Mining and Metallurgy (Mineragraphic Investigations)	500	500
Postmaster-General's Department (Radio Research)	5,000	5,000
Departments of Army, Navy, and Air (Radio Research)	10,000	10,000
Drug Houses of Australia (Division of Fisheries—Agar Production)	25	..
Commonwealth Fertilizers and Chemicals (Industrial Chemistry)	300	..
National Gas Association (Gas Investigations—Industrial Chemistry)	600	600
Australian Cement Manufacturers (Cement Investigations—Industrial Chemistry/Soils)	1,500	1,500
Apple and Pear Board—Thrips Investigations	77	..
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications)	24	..
Science and Industry Endowment Fund	2,088	2,088

* Expended as follows:—Boundary fencing and dams at Prospect, £154. Buildings at Prospect, £9,914. Construction of roadway at Prospect, £64. Buildings at Armidale, £2,854. Construction of roadway at Armidale, £501. Erection of cottage, McMaster Field Station, £3,627. Buildings at Deniliquin, £17,839. Buildings at Trangie, £10,742. Purchase of land, Kojonup, £981. Buildings at Crawley, £937. Electric installations at Glenthorne, £204. Acquisition of property at Albury, £5,400. Erection, lining and ceiling Army huts, Geelong, £3,278. Erection of buildings and cottage and acquisition of site, Geelong, £19,933. Alterations to buildings, Maribyrnong, £1,675. Conversion of "Quamby" into a laboratory, £7,572. Erection of laboratory, Fishermen's Bend, £4,497. Refund received from Department of Works and Housing in connexion with erection of biochemistry laboratory, Adelaide, £7,563.

A. Includes £31 on account of 1949-50 expenditure.
B. Includes £232 on account of 1949-50 expenditure.
C. Includes £5 on account of 1949-50 expenditure.
D. Includes £15 on account of 1949-50 expenditure.
E. Includes £125 on account of 1949-50 expenditure.

	Receipts 1950-51 and balances brought forward from 1949-50.	Expenditure 1950-51.
	£	£
Wool Scourers, Carbonizers and Fellmongers Federation of Australia (Wool Textile Research) ..	3,000 ..	..
Various Contributors (Foundry Sands Investigations—Division of Industrial Chemistry) ..	28 ..	..
Commonwealth Aircraft Corporation (Division of Metrology, N.S.L.)	1,167 ..	..
Australian Wine Board—Oenological Research	1,441 ..	1,441F
George Aitken Pastoral Research Trust—Rabbit Investigations ..	875 ..	500
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Textile Research)	8,102 ..	..
Revenue Fund—Fleece Analysis Laboratory (Animal Health and Production Investigations) ..	830 ..	..
Revenue Fund—Toxaemic Jaundice Investigations (Animal Health and Production Investigations)	1,241 ..	788
Revenue Fund—Contagious Pleuropneumonia Investigations (Animal Health and Production Investigations)	2,068 ..	800
Revenue Fund—Oestrus Experiment (Animal Health and Production Investigations) ..	3,580 ..	1,455
Revenue Fund—Sale of Contagious Pleuro-pneumonia Vaccine (Animal Health and Production Investigations)	5,300 ..	900
Revenue Fund—Cobram Field Station (Animal Health and Production Investigations) ..	2,622 ..	261
Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations)	2,076 ..	2,076
Revenue Fund—Anaplasmosis Investigations (Animal Health and Production Investigations) ..	96 ..	..
Revenue Fund—Parkville Laboratory (Animal Health and Production Investigations) ..	91 ..	..
Revenue Fund—Tooradin Field Station (Animal Health and Production Investigations) ..	1,367 ..	500
Revenue Fund—Poultry Breeding Investigations, Werribee (Animal Health and Production Investigations)	5,435 ..	3,510
Revenue Fund—Werribee Farm Mastitis Investigations (Animal Health and Production Investigations)	7,760 ..	2,905
Revenue Fund—Drought Feeding Investigations, Werribee (Animal Health and Production Investigations)	94 ..	..
Revenue Fund—National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations)	23,115 ..	11,186
Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations)	15,000 ..	..
Revenue Fund—Sheep Biology Investigations (Animal Health and Production Investigations) ..	14 ..	..
Revenue Fund—Bacteriological Investigations (Animal Health and Production Investigations) ..	5 ..	5G
Revenue Fund—Parasitological Investigations (Animal Health and Production Investigations) ..	4,561 ..	1,373
Revenue Fund—Wool Biology Investigations (Animal Health and Production Investigations)	96 ..	..
Revenue Fund—Regional Pastoral Research Station (Animal Health and Production Investigations) ..	40,893 ..	7,886
General Donations — Building Research Section	51 ..	..
Revenue Fund—Infertility, F. D. McMaster Field Station (Animal Health and Production Investigations)	5,807 ..	2,015
Revenue Fund—Veterinary Parasitology Laboratory (Animal Health and Production Investigations)	207 ..	..
Revenue Fund—Toxaemic Jaundice Investigations, Barooga, New South Wales (Animal Health and Production Investigations) ..	3,357 ..	800
Revenue Fund—Nutrition Laboratory (Biochemistry and General Nutrition Investigations) ..	12,416 ..	653
Revenue Fund—Plant Industry Investigations	11,334 ..	1,070
Revenue Fund—Stanthorpe Field Station (Plant Industry Investigations)	3,896 ..	..
Revenue Fund—Glen Lossie Field Station (Plant Industry Investigations)	11,029 ..	..
Revenue Fund—Deniliquin Regional Pastoral Laboratory (Plant Industry Investigations) ..	8,179 ..	..
Revenue Fund—Cooper Laboratory (Plant Industry Investigations)	496 ..	290
Revenue Fund—Entomological Investigations	1,140 ..	..
Revenue Fund—Griffith Research Station (Citricultural Investigations)	6,542 ..	2,039
Revenue Fund—Merbein Research Station (Viticultural Investigations)	13,926 ..	4,689
Revenue Fund—Division of Food Preservation and Transport ..	246 ..	135
Revenue Fund—Egg Investigations (Division of Food Preservation and Transport)	168 ..	..
Revenue Fund—Mining and Metallurgy	14 ..	..
Revenue Fund—Ore-dressing Investigations	1,236 ..	..
Revenue Fund—Fisheries Investigations	695 ..	..
Revenue Fund—Oyster Investigations	39 ..	39H
Revenue Fund—Physics	1,443 ..	..
Revenue Fund—National Standards Laboratory	35 ..	..
Revenue Fund—Metrology ..	3,102 ..	..
Revenue Fund—Dairy Investigations	24 ..	..
Revenue Fund—Electrotechnology	512 ..	..
Revenue Fund — Industrial Chemistry	2,569 ..	..
Revenue Fund—Radiophysics ..	115 ..	..
Revenue Fund—Tribophysics ..	1 ..	..
Revenue Fund—Merbein Research Station—Production of Pyrethrum	185 ..	..
Revenue Fund—Wool Textile Research	110 ..	..
Revenue Fund—Wool Wax Report Royalties (Information Service)	6 ..	..
Revenue Fund—Land Research and Regional Survey	25 ..	..
	369,268 ..	177,687

F. Includes £161 on account of 1949-50 expenditure.
G. Includes £5 on account of 1949-50 expenditure.

H. Includes £39 on account of 1949-50 expenditure.

3. Wool Research Trust Account.

A credit balance of £794,349 was brought forward from 1949-50 in the Wool Research Trust Account. A further £347,506 was received during 1950-51 from the Department of Commerce and Agriculture. Expenditure during 1950-51 was as follows:—

	£	£	£
Division of Animal Health and Production—			
Parkville—			
Sheep Physiology Investigations—Parkville	5,442		
Sheep Physiology Investigations—Tooradin	2,080		
Toxaemic Jaundice Investigations—Barooga	343		
Toxaemic Jaundice Investigations—Cobram	1,951		
McMaster Laboratory—			
Parasitology Investigations—New South Wales	3,535		
Parasitology Investigations—Tasmania	87		
Parasite Physiology and Toxicology	1,315		
Biochemical Investigations	2,237		
Physiology of Reproduction	787		
Dipping and External Parasites	713		
Drought Feeding Investigations	1,937		
Veterinary Parasitology Laboratory, Yeerongpilly—			
Animal Physiology Investigations at University of Queensland	1,072		
Sheep Biology Laboratory, Prospect—			
Administrative and General Expenses	1,083		
Fleece Analysis	14,456		
Wool Biology Investigations	9,969		
Strain Trial Investigations	5,802		
Regional Pastoral Laboratory, Armidale—			
Parasitology, Agrostology, and Field Investigations	34,826		
McMaster Field Station—			
Genetics and Animal Production Investigations	500		
Survey of Wool Production	1,641		
National Field Station, Gilruth Plains—			
Capital Expenditure	250		
Animal Breeding and Strain Trial Investigations	3,013		
Agrostology Investigations	267		
		93,306	
Division of Plant Industry—			
Agrostology Investigations	32,094		
Mineral Deficiency Studies	2,296		
		34,390	
Research Services—			
Agricultural Research and Extension Liaison	2,095		
Review of Wool Programme for Publication	704		
		2,799	
Division of Industrial Chemistry—			
Expenditure on Wool Textile Research—			
Chemical Physics Investigations	6,047		
Organic Chemistry Investigations	8,444		
Physical Chemistry Investigations	1,318		
Clover Infertility Tests, Western Australia	81		
		15,890	
Division of Biochemistry and General Nutrition—			
Biochemical and Nutritional Investigations	18,040		
		18,040	
Wool Textile Research Laboratories—			
Wool Textile Research	88,646		
		88,646	
Wild Life Section—			
Wild Life Survey	3,927		
		3,927	
Miscellaneous—			
Overseas Studentships	10,261		
		10,261	
			267,259
Grants from Wool Research Trust Account to Institutions undertaking extra-mural co-operative wool research—			
University of Adelaide—Waite Institute—Agrostology and Onion Weed Investigations	4,039		
University of Western Australia—Investigations at Institute of Agriculture, Western Australia	3,720		
Department of Agriculture, Western Australia—Sheep Infertility Investigations	2,955		
Roseworthy Agricultural College—Progeny Testing and Allied Studies	3,025		
Sydney Technical College—Wool Clip Analysis	3,200		
University of Queensland—Sheep Physiology Investigations	1,650		
University of Sydney—			
Animal Physiology and Sheep Infertility Investigations	1,360		
Dog Distemper	1,000		
Department of Agriculture and Stock, Queensland—			
Progeny Testing and Fertility Investigations	1,115		
Georgina River Disease (Poison Plants Committee)	300		
Gordon Institute of Technology, Geelong—Wool Textile Investigations	2,300		
Wool Industries Research Association, Leeds, United Kingdom—Wool Textile Investigations	1,254		
		25,918	
Grants from Wool Research Trust Account to Institutions undertaking research in Agricultural Economics relating to wool production—			
University of Western Australia	1,256		
Roseworthy Agricultural College	1,268		
Australian Wool Realization Commission	4,982		
Department of Commerce and Agriculture—Division of Agricultural Economics	27,917		
Market and Consumer Research Limited	961		
		36,384	
Miscellaneous administrative expenses	72		
		72	
			62,374
			329,633

4. Miscellaneous Services.

	£
Contribution to Commonwealth Agricultural Bureaux	20,358
Grant to Standards Association of Australia	33,000
Grant to Australian National Research Council	4,483
Contribution to Chair of Aeronautics at Sydney University (establishment and maintenance)	5,000
Grant to National Association of Testing Authorities	5,000
Review Conference of Commonwealth Agricultural Bureaux	886
Mediterranean Grasslands Conference and Study Course	710
	69,437

XXXVI. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wishes to acknowledge the assistance it has received from its Committees, the members of which have placed their knowledge and experience so freely at its disposal.

I. CLUNIES ROSS, Chairman.

F. W. G. WHITE
S. H. BASTOW
H. J. GOODES
A. B. RITCHIE
} Executive.

G. A. COOK, Secretary.

30th October, 1951.

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