1954–55.

(TWENTY-FIRST PARLIAMENT.)

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

SEVENTH ANNUAL REPORT

OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR THE

YEAR ENDING 30TH JUNE, 1955.

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COMMONWEALTH OF AUSTRALIA.

Commonwealth Scientific and Industrial Research Organization.

SEVENTH ANNUAL REPORT FOR THE YEAR ENDING 30TH JUNE, 1955.

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 the Act the Organization took the place of the Council for Scientific and Industrial Research, which in turn had, in 1926, taken the place of the Institute of Science and Industry.

The powers and functions of the Organization are similar to those of the former Council and include the initiation and carrying ont of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth or any Territory of the Commonwealth; 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; and acting as a means of liaison with other countries in matters of scientific research.

2. Executive.

Mr. H. J. Goodes, O.B.E., B.A., has been reappointed as a member of the Executive for a further period of three years.

3. Advisory Council.

Dr. L. B. Bull, C.B.E., D.V.Sc., formerly Chief of the Division of Animal Health and Production, has been co-opted to the Advisory Council.

4. Secretariat.

All branches of the Staff Section at Head Office have now been placed under the direct control of Mr. D. T. C. Gillespie, M.Sc., who has been designated Assistant Secretary (Staff).

5. Honours and Awards.

Sir Edward Lefroy, a member of the Advisory Council, was made Knight Bachelor in the Queen's Birthday Honours for his services to the Western Australian agricultural and pastoral industries.

Mr. W. A. Gunn, a member of the Advisory Council, was made a Companion of the Order of St. Michael and St. George for his services to the pastoral industry in Queensland.

Dr. H. C. Forster, Assistant Executive Officer, was elected Federal President for 1955 of the Australian Institute of Agricultural Science.

Dr. D. F. Martyn, Chief Scientific Officer of the Radio Research Board, was elected by the Physical Society of London as Charles Cree Medallist for 1955, in recognition of his outstanding researches concerning the ionosphere. Dr. Martyn was also invited to be Scott Lecturer at the University of Cambridge for 1954.

Mr. N. A. Esserman, Chief of the Division of Metrology, was one of five new representatives of various countries who were elected to the International Weights and Measures Committee of the Bureau Internationale des Poids et Mesures in Paris.

Dr. C. H. B. Priestley, Chief of the Division of Meteorological Physics, was elected a member of the Executive Committee of the International Meteorological Association of the International Union of Geodesy and Geophysics.

Dr. M. J. D. White, Senior Research Fellow in the Division of Plant Industry, was elected Fellow of the Australian Academy of Science.

Mr. A. T. Dick, Principal Research Officer of the Division of Animal Health and Production, and Dr. A. M. Mathieson, Principal Research Officer of the Division of Industrial Chemistry, were jointly awarded the David Syme Research Prize for 1954 by the University of Melbourne, for the most distinguished contributions during the preceding two years in the fields of biology and chemistry respectively.

Dr. A. J. Hodge, Research Officer of the Division of Industrial Chemistry, was awarded the Rennie Memorial Medal for 1954 by the Royal Australian Chemical Institute, for the year's best contribution to the development of chemical science in Australia.

Dr. D. E. Weiss, Senior Research Officer of the Division of Industrial Chemistry, was awarded the Grimwade Research Prize for 1955 by the University of Melbourne, for his study on the separation of materials by absorption.

Dr. H. E. Dadswell, Assistant Chief of the Division of Forest Products, was awarded for the first quarter of 1955 the Walker Ames Professorship in Forestry at the University of Washington, Seattle.

Dr. R. N. Bracewell, Senior Research Officer of the Division of Radiophysics, was invited by the University of California to give a series of lectures on radio astronomy as Visiting Assistant Professor.

Dr. D. Spencer, Research Officer of the Division of Plant Industry, was awarded a post-doctoral fellowship at the McCollum-Pratt Institute, John Hopkins University, U.S.A.

Dr. R. A. Durie, Research Officer, Coal Research Section, was awarded a Fellowship by the National Research Council of Canada.

Mr. M. Michael, Technical Officer, Division of Indnstrial Chemistry, was awarded the Henry Ellison Research Fellowship at the University of Sheffield.

6. Retirements.

Miss E. L. Archer, M.Sc., has retired from her position as Chief Librarian of the Organization. Miss Archer had been on the staff of the Organization and its two predecessors (the Council for Scientific and Industrial Research, and the Institute for Science and Industry) from the earliest years of their formation.

Dr. H. Thompson, M.A., D.Sc., has retired from his position as Chief of the Division of Fisheries. Dr. Thompson was the first Chief of the Division and during the seventeen years of his leadership it has become one of the leading laboratories of its kind in the world.

7. New Division.

The Section of Meteorological Physics, with headquarters at Aspendale, Victoria, has been designated a Division, and Dr. C. H. B. Priestley, M.A., Sc.D., Chief of the Division.

8. Irrigation Research Stations.

In view of the impending retirement of Mr. E. S. West, B.Sc., M.S., Officer-in-Charge of the Irrigation Research Station at Griffith, it was decided that the administration of the Station at Griffith and the Commonwealth Research Station at Merbein should be brought under the one direction. Mr. F. Penman, M.Sc., has been appointed to the position of Senior Officer-in-charge of the two Irrigation Research Stations.

9. Gift and Bequest from Sir Frederick McMaster.

The late Sir Frederick McMaster, of "Dalkeith", Cassilis, New South Wales, shortly before his death in November, 1954, presented the sum of £52,000 to the Organization for the construction of a new wing to be attached to the McMaster Animal Health Laboratory, Sydney.

The McMaster family have now made a succession of gifts to science through the years, the McMaster Laboratory itself being originally established as the result of a gift of £20,000 to the former Council for Scientific and Industrial Research in 1930.

The new wing will be named the Ian McMaster Wing in honour of Sir Frederick's only son, the late Captain Ian McMaster, who was killed in action at the battle of El Alamein.

In addition to this gift, under the will of the late Sir Frederick McMaster, the Organization, as residuary legatee, has become the principal beneficiary of the estate. Sir Frederick had always taken a keen interest in current scientific research and its relation to the rural industries. It was Sir Frederick's wish that the money which he has left to the Organization should be used by the Executive to further the Organization's efforts in research for veterinary science or agriculture.

Sir Frederick McMaster asked that the Organization ensure that a portion of his station property "Dalkeith" be used to demonstrate the agricultural and pastoral principles of reserve stocking which he developed there.

The Executive wishes to acknowledge its indebtedness to the McMaster family which has now made such a generous succession of gifts to science through the years.

10. Co-operative Research with Industry.

Support for the Australian Leather Research Association and the Bread Research Institute of Australia has been continued under financial arrangements whereby the Organization makes a contribution to their running costs.

Following negotiations between the Executive, the Australian Wine Board, and the Department of Trade and Customs, the *Wine Research Act* 1955 was passed by the Commonwealth Government to permit the establishment of an Australian Wine Research Institute. This Institute will have its own scientific facilities and will undertake research on behalf of the wine industry. It will continue and intensify the research at present carried out by the Organization's Oenological Research Section in Adelaide which will eventually be transferred to the Institute. The Australian Wine Research Institute thus takes its place as the third co-operative research establishment organized on the research association principle, sponsored by the Organization.

During the current year negotiations have been effected for a number of new sponsored research projects to be undertaken on a co-operative basis with industry and other establishments. These projects include—

Investigation by the Division of Building Research on defects in the decoration of fibrous plaster, sponsored by the Associated Fibrous Plaster Manufacturers of Australia; study by the Division of Industrial Chemistry of the extraction of uranium from unfiltered ore pulps, sponsored by the Australian Atomic Energy Commission; a project in the Animal Genetics Section, sponsored by the New South Wales State Cancer Council, on the breeding of mice sensitive and insensitive to oestrogens given subcutaneously; a cloud seeding programme by the Division of Radiophysics undertaken on behalf of the Snowy Mountains Hydro-Electric Authority; a research project on tin plate for canning purposes being undertaken by the Division of Food Preservation and Transport for the Commonwealth Can Makers' Association; a project on brown coal in the Mineragraphic Section sponsored by the State Electricity Commission of Victoria; a study of marine fouling in the Division of Fisheries sponsored by the Department of the Navy; a project on Farm Mechanization sponsored by the Australian Dairy Produce Board and the Rural Credit Development Fund of the Commonwealth Bank of Australia; an investigation of cheese making in the Dairy Research Section sponsored by the Australian Dairy Produce Board.

The above co-operative research projects are additional to those noted in previous reports. A full list of contributions and donations for research received by the Organization is listed in Chapter XXXV., Section 2.

During the year the Executive invited Professor R. S. Edwards to visit Australia to discuss the general problems of the application of science and research to industry. Professor Edwards is Professor of Economics (with special reference to industrial organization) at the London School of Economics, and is a leading authority on co-operative research. He gave a number of public lectures, visited firms and business executives throughout the Commonwealth, and consulted with officers of the Organization. He also read three papers on industrial research at a week-end residential conference at Healesville, which was arranged by the Australian Institute of Management. This conference aimed to explore the possibilities for the development of co-operative industrial research associations and sponsored research, and to discuss ways whereby existing research facilities in Australia can be used to better advantage in assisting industry.

For some time the Executive has felt the need for strengthening the liaison between the Organization and Australia's rapidly growing secondary industries. It has been decided, therefore, to appoint an Industrial Research Liaison Officer who will lead a small Section at Head Office to foster liaison with industry.

11. Giant Radiotelescope.

The Carnegie Corporation of New York has made a gift of 250,000 dollars to the Organization towards the cost of building a giant radiotelescope in Australia. This is a generous tribute to the contributions of the Division of Radiophysics to the new science of radio astronomy. Subsequently, the Commonwealth Government has offered to meet half the cost of the proposed radiotelescope provided the remainder can be found from other sources. A Radio Astronomy Research Trust on which the Right Honourable R. G. Casey, Minister in charge of C.S.I.R.O., has agreed to act as Chairman, is being established to be responsible for enlisting support for the project and for receiving and administering the funds donated. A number of private donations have already been received.

12. Australia's Water Resources.

The availability of water supplies is perhaps the greatest natural limiting factor in the Australian environment. The Organization has for a number of years been engaged on various research projects bearing upon this problem. Two significant developments

in this field of research which are described in this Report have both now reached a stage of large-scale practical tests.

The researches being undertaken by the Division of Radiophysics in cloud physics and rainmaking are reported in Chapter XXVIII., Section 8. As the result of detailed study since 1947 on the properties of single clouds, the emphasis of this work is now developing to include field trials of methods of artificial seeding by which rainfall might be increased over a relatively wide area.

In Chapter XVIII., Section 5 (*g*), current development is described in the investigations being undertaken by the Division of Industrial Chemistry in the use of cetyl alcohol to retard evaporation of water from dams and other open storages. Preliminary work on this technique has been so promising that a series of field trials are being undertaken in several States to gauge the potentialities of the method on a full-scale basis.

Both these projects therefore hold out promise of significant returns in relation to the availability of water supplies on the Australian continent.

13. Research Staff.

In the last two Annual Reports attention has been drawn to the difficulty the Organization has experienced in attracting first-class men to research careers in science, and the need for improving the financial prospects of research scientists.

It is pleasing to be able to report that this situation has now been largely relieved by the increases in research salaries which have followed, not only from the recent marginal increases, but also from the Public Service Arbitrator's Determination No. 51 of 1954 providing for the adjustment of the salaries of officers in the research classifications.

During the year under review, although the net gain in recruitment of research staff was only 23, there was a considerable improvement in recruiting during the last months. Further improvement in this rate is anticipated as the impact of the salary increases becomes effective, and greater numbers of young people are attracted to careers in science.

14. Overseas Visitors.

A number of leading scientists from overseas visited Australia during the year, many of them under the auspices of the Organization. In their visits to laboratories and establishments they gave much stimulation and help to Australian research.

Dr. D. T. A. Townend, Director-General of the British Coal Utilization Research Association, spent some months in Australia to consult with the Executive, officers of the Coal Research Section, and others working on fuel research.

Professor R. S. Edwards, Professor of Economics at the University of London, spent two months with the Organization advising the Executive on the organization of industrial research (*see* Section 10 of this Chapter).

Professor W. S. Phillips, Professor of Botany and Head of the Department of Botany and Range Ecology at the University of Arizona, visited Australia under a Fulbright grant to study pasture improvement and water conservation. He spent some time with officers of the Division of Plant Industry at Brisbane, Armidale, and Deniliquin.

Mr. G. V. Jacks, Director of the Commonwealth Bureau of Soil Science, spent five weeks in Australia studying agricultural research.

Mr. A. W. Marsden, Director, Commonwealth Bureau of Dairy Science, visited Australia in the course of a tour of the Commonwealth countries to investigate current practices in dairy science. He spent seven weeks in Australia and visited the centres of dairy production in all States of the Commonwealth.

Professor Samuel Brody and Dr. R. E. Stewart, of the College of Agriculture, University of Missouri, United States of America, visited Australia at the invitation of the Division of Animal Health and Production to inspect and advise on the design and operation of the climate control rooms being constructed at the Sheep Biology Laboratory, Prospect, New South Wales. Their experience and advice have proved of great value to our scientists working on both the biological and engineering aspects of the Prospect investigations.

Dr. James A. Ibers, of the California Institute of Technology, was awarded a United States National Science Foundation Post-Doctoral Fellowship to visit the Division of Industrial Chemistry for twelve months to work with the Electron Diffraction Research Group in the Chemical Physics Section.

Dr. J. W. Seinhorst, Head of the Nematology Department of the University of Wageningen, Holland, came to Australia for six months as a research Fellow and has worked with the Commonwealth Research Station, Merbein. Dr. Seinhorst has surveyed the nematode problem in Australia and has reported on the possible steps which might be taken to cope with it.

Dr. A. E. Pierce, Principal Scientific Officer of the United Kingdom Agricultural Research Council, recently accepted an Ian McMaster Research Fellowship to undertake research in protozoology for twelve months at the McMaster Laboratory of the Division of Animal Health and Production. He is at present surveying problems of protozoology which arise in Australia.

Mr. L. P. Smith, Head of the Agricultural Meteorological Branch of the British Meteorological Office, visited Australia as part of a world tour to study the application of meteorology to agriculture. In Australia he was particularly interested in the practice of water conservation and irrigation.

Professor Rogoff, of the South Dakota State College, United States of America, visited Australia under the Fulbright Scheme to undertake research with the Division of Entomology on the factors which cause the Australian sheep blowfly to be attracted to and to oviposit on sheep.

Professor James Thorpe, University of Indiana, United States of America, visited Australia for a period of six months as a Fulbright scholar. He is an eminent pedologist and spent most of his time with the Division of Soils.

Professor Perry Stout, Chairman of the Department of Plant Nutrition, University of California, is visiting Australia under a Fulbright Award. He will spend a year with the Division of Biochemistry and General Nutrition in Adelaide and will collaborate with officers of the Division in studies of micronutrient element deficiencies of plants.

Dr. van der Plank, Chief of the Division of Plant Pathology, Pretoria, South Africa, visited the Division of Plant Industry for discussions with plant pathologists as part of a tour of inspection of the Australian potato industry.

Dr. J. C. Smith, Lecturer in Organic Chemistry at the Dyson Perrins Laboratory, University of Oxford, is making a three months' visit to the Organization as a guest worker at the Division of Industrial Chemistry in Melbourne. Dr. Smith was awarded a bursary under the recently inaugurated Royal Society and Nuffield Foundation Commonwealth Bursaries Scheme, which enabled him to make this visit.

In addition, a number of distinguished scientists from Asia attending the Pan-Indian Ocean Science Congress in Perth, visited the Organization's laboratories in the eastern States. Short visits were paid by Professor H. J. Bhabha, F.R.S., Director, Tata Institute of

Fundamental Research, Bombay; Dr. J. N. Mukerjee, formerly Director, Indian Agricultural Research Institute, New Delhi; Dr. Bashir Ahmad, Director, Lahore Regional Laboratory, C.S.I.R., Pakistan; and Dr. Panikkar, Director, Fisheries Research, D.S.I.R., India.

15. Buildings and Accommodation.

During the year the following buildings were completed:—

Sheep Biology, Prospect.—Cottage No. 2, Amenities Block, and Rabbit House for Animal Genetics Section.

Wool Textile, Ryde.—Extension No. 2 Workshop/store.

Dairy Research, Highett.—Main Laboratory and Plant and Services building.

Wool Textile, Parkville.—West Wing building.

Meteorological Physics, Aspendale.—Garage/store.

Regional Laboratory, Deniliquin.—Four cottages in Township and Dining-room at Falkiner Memorial Field Station.

Regional Laboratory, University of Western Australia; Central Block, Canberra.

A 62-acre property at Camden known as "Harben Vale", on which is a large partially completed house, also was acquired (*see* Section 16 of this Chapter).

The following projects are in course of construction:—

Sheep Biology, Prospect.—Climate controlled building.

Wool Textile, Ryde.—Main building.

Zoology School, University of Sydney.—Extension for Animal Genetics Section.

Fisheries, Cronulla. — Small Radiochemistry Annexe.

Radio Research Board, Camden.—Completion of building.

Field Station, "Chiswick".—Bachelors' Quarters (to replace quarters destroyed by fire).

Entomology, A.C.T.—Air-conditioned Insectary.

"Glen Lossie" Field Station.

Industrial Chemistry, Fishermen's Bend.—Workshop.

Food Preservation, "Stowell", Hobart.—Annexe.

16. Radio Research Board, Field Station.

A new property, "Harben Vale", has recently been acquired at Camden, New South Wales, for the establishment of a field station for the Radio Research Board.

The Board will use the new property to carry out research on radio transmission and studies of the upper atmosphere. "Harben Vale" is removed from built-up areas and is sufficiently free of electromagnetic interference to serve adequately for the Board's investigations.

The new property includes a large unfinished house which is being modified to create laboratories, offices, workshops, and living quarters, for staff permanently stationed in the area.

17. Collaboration with Universities.

The Organization's work in the universities is reported in various places in the main body of this report. However, during the year several important arrangements were made with universities for the integration of research projects.

At the University of Western Australia negotiations have been completed for certain aspects of the work of the Timber Mechanics Section of the Division of Forest Products to be undertaken in the Engineering School under the direction of Professor Cooper. Until 1954 Professor Cooper was Officer-in-charge of the Timber Mechanics Section at the Division's Laboratory in Melbourne. The Division has transferred some of its staff to the University of Western Australia and has commenced work on a project to investigate the influence of various defects on the strength of scantling timber.

The Division is interested in developing research on timber in the Australian universities so that engineering students may become familiar with timber as a structural material and realize the important application it has in engineering construction.

The Council of the University of Melbourne has accepted the Executive's offer to transfer to the university on indefinite loan the high-speed electronic computer developed and constructed in the Division of Radiophysics. The computer will be attached to the University's Department of Applied Mathematics under the supervision of Professor T. M. Cherry. The Organization is meeting the cost involved in transporting the computer to Melbourne, and is making available research and technical staff to install the instrument at the University. The Executive has agreed to make a grant of £3,000 per annum to the University towards the maintenance of a mathematical computing centre, in return for which some portion of the working time of the computer will be devoted to the solution of C.S.I.R.O. mathematical problems.

The Organization and the University at New England have agreed that pastoral research by the Regional Pastoral Laboratory at Armidale and by the University's newly established faculty of Rural Science shall be closely linked so that the resources of both can be related and used to the best advantage. A small Research Committee, comprising members of the University and members of the Organization, has been established to effect close co-operation. The resources of the Field Station at "Chiswick", including additional laboratory facilities which are to be provided there, will be available to workers from the University. Similarly, the resources and laboratories of the Faculty of Rural Science will be available to the Organization's staff who are engaged on field experiments or laboratory researches, under the general direction of the Research Committee.

The Organization recognizes the great importance of collaboration with the universities and has always endeavoured to maintain and extend these arrangements for co-operative research wherever possible. It is realized that arrangements of this nature stimulate scientific research, and the Organization gratefully acknowledges its debt to the universities.

The Organization desires to acknowledge the assistance of the University of Adelaide in providing accommodation for the Clay Mineralogy Section of the Division of Soils in the Geology Department of the University. This will be a temporary arrangement for three years until a new building is available for the Division of Soils. The Organization is providing funds to make structural alterations and provide the necessary services for installation of X-ray and other equipment in the University building.

The Organization has agreed to make a grant for five years to the University of Adelaide towards the establishment of an Animal Ecology Unit within the Department of Zoology. In addition a special grant of £1,500 has been made towards the cost of the necessary equipment and teaching facilities.

18. Science and Industry Endowment Fund.

During the year, the Executive, as Trustees of the Science and Industry Endowment Fund, approved of grants to assist research workers, as follows:—

Mr. Tarlton Rayment, for taxonomic work on bees; Miss M. McKay, for work on the effect of seaweeds on estuarine environment; Dr. I. Cookson, to enable her to prolong her stay in Paris where she was studying planktonic microfossils; Dr. D. J. Pearson, for work on the comparative anatomy and embryology of marsupials; Mrs. P. Mather, for work on ascidians; Mr.

N. V. Dobrotworsky, for work on the systematics and ecology of Victorian mosquitoes; Mr. A. W. Parrott, for taxonomic work on parasitic wasps; Mr. I. C. Carnaby, for ornithological research; Mr. H. Womersley, for acarological studies; and Miss D. F. Sandars, to enable her to continue her helminthological studies in England and Europe.

A grant of £100 was made to the Bird Observers' Club to cover the cost of publication of the 1954 Bird Count Lists and to prepare for the 1955 Count. In addition, a studentship for overseas training was awarded to Mr. I. G. White who will study biochemistry of mammalian semen at the Molteno Institute.

19. Miscellaneous Grants.

As agents for the Commonwealth Government, the Organization continued to supervise grants to the following:—

The Commonwealth Agricultural Bureaux; the Standards Association of Australia; the Chair of Aeronautics, Sydney University; the Australian and New Zealand Association for the Advancement of Science; the Pan-Indian Ocean Science Congress.

20. Overseas Visits, Fellowships, and Studentships.

During the year the Chairman, Sir Ian Clunies Ross, commenced an overseas visit to the United Kingdom to attend the Commonwealth Agricultural Bureau Review Conference in London. He travelled to England via Canada, where he consulted with officers of the National Research Council and other establishments. He also visited Rome to consult with officials of the Food and Agricultural Organization and will spend a few days in Egypt studying recent developments in agriculture.

The Chief Executive Officer, Dr. F. W. G. White, undertook an assignment as Adviser on Scientific Research under the U.N.E.S.C.O. Technical Assistance Programme for Egypt. He spent a period of five weeks in Egypt studying the development and application of science in that country, and advised the Egyptian Government on the future policy for its National Research Council.

As in previous years, a number of officers of the Organization were sent overseas for periods ranging from two to twelve months to acquire experience and training in new techniques and to collect general information on developments in scientific research.

Seven officers were sent overseas primarily to attend important international conferences, and in addition six senior officers were invited to visit overseas institutions for consultations concerning special aspects of their work.

Seven overseas students were given awards for training in fields of science which will fit them for research positions upon completion of their training. Four traineeships and one divisional studentship were also awarded. One studentship was awarded from the Science and Industry Endowment Fund. At the close of the year 21 overseas studentships and traineeships were current.

Seventeen studentships were awarded earlier in 1955 for post-graduate research in Australian universities, raising the total of those receiving training under this scheme to 28.

An arrangement has been concluded with the Department of Scientific and Industrial Research and the Agricultural Research Council in the United Kingdom whereby a number of the Organization's Australian studentships will become available for applicants in Great Britain. This makes it possible for a number of students from the United Kingdom to come to Australia to undertake post-graduate work, and it is hoped that this will counterbalance to some extent the regular flow of Australian graduates to post-graduate work in United Kingdom universities.

The first appointee under this scheme is Mr. H. Rishbeth from Cambridge University, who has recently commenced work at the Division of Radiophysics.

Since the commencement of the Colombo plan in 1950, 39 students have trained with the Organization for periods of study extending up to two years, and many others have visited the Divisions and Sections for shorter periods. Each year an increasing number of requests are being received for the Organization to provide training under the plan.

21. Finance.

Chapter XXXV. gives details of the expenditure of £5,449,643 incurred during 1954-55 by the Organization from all funds at its disposal. The major portion of this sum was derived from the Commonwealth Treasury—£3,989,318 was expended in connexion with normal research activities, £109,625 on grants to bodies such as the Commonwealth Agricultural Bureaux, and £9,335 on capital works under the control of the Organization. The remainder was expended on investigations financed from contributions, viz., £713,221 from the Wool Research Trust Account, £356,951 from the wool Industry Fund, £89,543 from miscellaneous receipts, and £181,650 from grants including special revenue. Certain other expenditure was incurred by the Commonwealth Department of Works on building projects for the Organization from funds controlled by that Department. Likewise the Department of the Interior met the costs of rentals and acquisition of sites and buildings for the Organization from funds made available to that Department by the Treasury.

The Organization is particularly gratified by the way in which various 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 of Australia (through the Rural Credits Development Fund), Australian Wool Board, Australian Meat Board, Australian Dairy Produce Board, Australian Wine Board, Australian Egg Board, the Queensland Meat Industry Board, the New South Wales Department of Agriculture, the New South Wales Water Conservation and Irrigation Commission, the Metropolitan Meat Industry Board of New South Wales, the George Aitken Pastoral Research Trust, Burdekin Bequest, the Alexander Fraser Memorial Fund, the Dried Fruits Control Board, the Australian Dried Fruits Association, the dried fruits industry, the National Gas Association, Australasian Institute of Mining and Metallurgy, State Electricity Commission of Victoria, Australian Cement Manufacturers' Association, the wool textile industry, the timber industry, and the pulp and paper industry.

22. 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 seventeen, comprise the major establishments, which may be further subdivided into Sections; there are also nineteen 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 Divisions or Sections 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 Melbourne and associated with it are the Organization's Central Library, Agricultural Research Liaison Section, Cine Unit, and Editorial, Publications, and Translation groups. The Organization also maintains Australian Scientific Liaison offices in London and Washington.

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

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

Entomology, with head-quarters and main laboratories at Canberra, a smaller laboratory in Sydney, and field stations at Trangie, New South Wales, Rockhampton, Queensland, and Perth.

Animal Health and Production, with head-quarters in Melbourne and main laboratories in Melbourne, Sydney, Prospect, New South Wales, and Brisbane; and field stations at Armidale and Badgery's Creek, New South Wales; Cunnamulla, Amberley, Belmont, and Rockhampton, Queensland; and Werribee and Tooradin, 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, and branch laboratories at Perth, Canberra, Brisbane, and Hobart.

Forest Products, Melbourne.

Food Preservation and Transport, with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane and Hobart, 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 Hobart and Thursday Island.

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

Radiophysics, Sydney.

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

Tribophysics, Melbourne.

Building Research, Melbourne.

Mathematical Statistics, Adelaide.

Meteorological Physics, Melbourne.

The following are the Sections:—

Irrigation Research Stations, at Merebin, Victoria (Murray Irrigation Areas), and Griffith, New South Wales (Murrumbidgee Irrigation Areas).

Plant Fibre, Melbourne.

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

Mineragraphic Investigations, Melbourne.

Oenological Research, Adelaide.

Dairy Research, Melbourne.

Tracer Elements Investigations, Melbourne.

Coal Research, Sydney.

Physical Metallurgy, Melbourne.

Wildlife Survey, with head-quarters in Canberra and field stations at Perth, Albury, New South Wales, and Aberdoss, near Marble Bar, Western Australia.

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 Alice Springs, Northern Territory, Katherine, Northern Territory, and in the Kimberley region, Western Australia.

Agricultural Research Liaison Service, Melbourne.

Animal Genetics, Sydney.

Central Experimental Workshops, Melbourne.

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

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

II. SOILS.

1. General.

Scientific appreciation of Australian soils is basic to any proper land use. The efficient exploitation of existing land resources, improvements in farming method, more intensive cultivation, techniques for pasture improvement, and measures for soil conservation, all require a fundamental knowledge of the soil.

The Organization's work in this field is undertaken by the Division of Soils with head-quarters at the Waite Agricultural Research Institute of the University of Adelaide. However, some work on soils and their behaviour under irrigation is undertaken at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and at the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales (*see* Chapter IV., Sections 2 and 3). The Central Experimental Workshops in Melbourne have developed a powered earth auger, and this work is reported in Section 9 of this Chapter.

Division of Soils.—The Division is the central and main body engaged in soil research in Australia, and does research into the classification, properties, and problems of Australian soils both of an applied and of a fundamental nature. The primary objectives of this research are—

(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 State advisory and administrative bodies.

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

(iv) Applied research into engineering properties of soils and soil mechanics.

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

The newer developments in pedology, mineralogy, and microbiology mentioned in the last annual report have been pushed forward. Mineralogy is of increasing importance in soil studies, emphasis being placed not only on X-ray and related investigations in clay mineralogy but also on the petrographic study of the non-clay fraction. A new Section dealing with clay mineralogy has been set up and soil mechanics work has been separated as an independent Section with headquarters in Melbourne until other accommodation is available (*see* Section 8 of this Chapter). The co-operation of the Universities of Adelaide and Melbourne, in making accommodation available to the Division, is gratefully acknowledged.

During the year five research staff have been overseas for varying periods and two away on studentships. A senior officer was sent as an Australian delegate to the International Soils Congress at Leopoldville, Belgian Congo. He was honoured by election as a vice-president of the Congress and as chairman of Commission V. on soil classification and pedology.

The Division was fortunate in having the close association with Professor James Thorp of Indiana, United States of America, on a Fulbright research grant. Co-operation with F.A.O. and the Colombo plan has been maintained during the year.

2. Soil Survey and Pedology.

(Division of Soils.)

During the past year the field programme of this Section has embraced soil surveys in areas where land settlement is in progress, where fertility problems exist, where irrigation is projected, and where there are various problems associated with established horticulture. However, an increasing emphasis has been placed on pedological studies and on an attempt to place the survey programme on a systematic geographical basis. Both these activities will absorb an increasing proportion of the activities of this Section in the future.

Activities have taken place in all States and detailed surveys have covered 200,000 acres and reconnaissance surveys some 12,000 square miles. Further work has been done in Queensland towards the compilation of an atlas of Australian soils.

(*a*) *Western Australia.*—Work on the coastal plain during the year has been principally concerned with a detailed soil survey in the Pinjarra-Waroona area in connexion with the proposed extension of irrigation in that district. The total area involved is 180,000 acres, of which 77,000 acres have now been surveyed. The soil pattern corresponds with that generally found on the coastal plain, in the form of a belt of flat alluvial soils extending westwards from the Darling Scarp, and separated from the sea by an area of sand dunes and swamps. The alluvial soils are those under consideration for irrigation, and for the most part consist of sandy surface soils overlying clay subsoils.

During the post-war years a number of soil surveys, both detailed and broad-scale, have been carried out in the Great Southern district, largely in connexion with War Service Land Settlement projects. A beginning has now been made in the preparation of some of this material for publication, attention being first directed to the 900 square miles covered by Lands Department sheet 444/80. The area includes the towns of Mount Barker and Cranbrook, and the War Service Land Settlement projects at Rocky Gully, Perillup, and Kybelup. Previously the whole area had been surveyed at the soil association level, supported by detailed soil surveys in some of the Land Settlement areas. The summer months of this year have been devoted to the revision and correlation of the work already done, a detailed survey of a further 5,500 acres in the north-west of the area, and the collection of land-use data.

A study of the soils of the Western Australian wheat belt has been commenced towards the end of the year with a detailed soil survey of some 5,000 acres east of York. The area is sharply dissected, lateritic breakaways being a prominent feature of the landscape.

(*b*) *South Australia.*—The soil survey of the Barossa District has been continued from last year and is now complete with the exception of some pedological studies which will be concluded during the latter part of 1955. Field work at a moderate level of detail has been completed in the two remaining units, the Angaston-Springtan and the Lyndoch-Williamstown areas. The former unit covers an area of about 55,000 and the latter an area of about 15,000 acres. Reconnaissance mapping has been completed also over an area of about 16 square miles in the Mt. Kitchener-Pewsey Vale area.

A soil survey of about 23 acres in Broadview Gardens, a suburb of Adelaide, has been made to provide basic soils data for investigations into the bad cracking of houses which has occurred after about five years' occupation.

Field work has recently begun on a new soil survey project in the areas around Lakes Alexandrina and Albert near the mouth of the Murray River in South Australia. The total area likely to be involved is between 1,000 and 1,500 square miles, of which about 100 square miles have been examined at present.

Field and laboratory work on seasonal changes in soil salinity in the Tintinara district is complete and a detailed report has been prepared for publication. Other investigations have involved the sampling of ground-waters and carbonate materials in soils, with the object of studying the influence of hydrological conditions on soil salinity and deposition of carbonates in soils.

The soil survey and pedological study of the soils at Yudnapinna station which was commenced in an exploratory way last year have now been undertaken as a full-scale project involving both detailed and soil association surveys. Observations on run-off and infiltration on catchment areas of earth tanks have also begun.

(*c*) *Victoria.*—A joint report on soils of the Shire of Kowree, western Victoria, has been completed by officers of the Division and of the Soil Conservation Authority of Victoria. Further information on soil fertility is being sought in experiments by the Soil Chemistry Section. Samples of typical soils have been collected for microscopic examination.

(*d*) *Tasmania.*—The only units added to the regional survey this year have been (i) parts of the Ellendale and Cuse rectangles, and (ii) a narrow strip along the west coast, in the Balfour and Bluff Point rectangles. The former unit will serve also as a preliminary reconnaissance to guide more intensive surveys proposed for the Ellendale and Cuse rectangles next year.

The soil map of Flinders Island has been drafted and compilation of the report is proceeding.

Field work in the past season in the Burnie-Table Cape area has been confined to the detailed survey of a strip 1 mile wide, running inland for a distance of 13 miles from Wynyard on the coast. The dissected basalt plateau rises gradually from near sea level on the coast, to 2,000 feet behind the surveyed area. Rainfall increases and temperature decreases with increasing elevation, and the soil units tend to run in belts parallel to the coast. The detailed survey thus acts as a cross-section, on the basis of which may be defined the soil associations to be used as units for the broader-scale mapping of the district. Of the basaltic soils so far examined in the detailed survey nearly all are krasnozems and the differences between the soil series are slight and difficult to recognize. A complicating factor in the soil pattern is the prevalence of land slides or slumps, which have been a major factor in

the erosion of the landscape. Nevertheless the area offers good opportunities of the study of pedogenesis in krasnozems. On the land-use side, most of the area of basaltic soils is capable of considerable improvement. The belt nearer the coast is closely settled with a fairly stable agriculture, but on the higher country inland, because of early agricultural failures and because pine forests grow well there the relative economy of agriculture and silviculture is an important question. On more developed properties in the higher country, pasture top-dressing with molybdenum is becoming general and is largely replacing the former use of lime which is now thought to have been effective mainly in increasing the availability of molybdenum. Recent investigations of the Department of Agriculture are indicating that cobalt deficiency is possible on the krasnozems throughout the area surveyed.

The unsatisfactory position with regard to base maps has eased somewhat, partly because of efforts made by officers during the past year in compiling a photogrammetric base map for the Burnie-Table Cape survey, and partly because of the increasing production of such maps by other departments. These include a map produced at the Division's request by National Mapping Section, Department of the Interior, for the soil survey of Flinders Island. Adequate base maps now exist for each of the projects mentioned above, with the exception of the regional survey. However, it may still be necessary for the Division itself to compile base maps for some areas which other departments cannot handle at present.

A beginning has been made with the examination of the potassium status of Tasmanian soils, initially at Frodsley Estate, Fingal. Widespread deficiencies of potassium in soils and pastures are becoming recognized in Tasmania, and it is hoped that basic studies of potassium statns of Tasmanian soils can be expanded.

(*e*) *South-east Region.*—Field work has been based on Deniliquin, Griffith, and Canberra. The Billabidgee area near Griffith, which has been proposed for irrigation development, has been partly surveyed by the joint effort of staff from C.S.I.R.O., the New South Wales Irrigation Commission, and the Department of Agriculture. An area of 350,000 acres out of the total of about 700,000 acres has been covered by a stage 2 survey.

An investigation in the Griffith-Yenda district in the Murrumbidgee Irrigation Area involving about 20,000 acres has been begun.

The Denimein district, near Deniliquin, of 130,000 acres, has been surveyed. This area is already irrigated and the soils are mostly "difficult" for irrigation. A soil map and discussion of the problem is being prepared.

A study was made of the soils and landscapes near Canberra, initially as a study of the four lower river terraces involving an area of about 5,000 acres. Further study of trenches opened up by civil engineering authorities, and of deep bores, is contributing to a very useful appreciation of the local processes of landscape development, and the relation of soils to these landscapes.

(*f*) *Queensland Region.*—The Darling Downs survey has been continued with soil studies and association mapping covering most of the Kurrawa 1-mile Military Sheet of approximately 500 square miles during the year. This work completes the mapping part of this project and Soil and Land Use Reports covering the Toowoomba and Kurrawa Sheets are in preparation. In the Kurrawa area the plains east of the Condamine River are typical of the productive grain lands of the western Darling Downs. They consist mainly of deep black earth soils with a smaller area of grey soils of heavy texture and some patches of solodized solonetz soils. Though the black earths are fertile and their soil phosphate levels are generally very high, an area of relatively low total phosphate content has been revealed by the survey. The undulating to hilly lands west of the Condamine River mostly overlie Blythesdale sandstones which have been laterized in the past and subsequently dissected. The soil pattern is dominated by various groups of solodized solonetz and solodic soils with some podzols and podzolics and small patches of gleyed soils. Their nutrient status is generally low and the poor physical properties of the salt-affected soils make them rather droughty. The undulating to rolling lands are used for grazing with a little cropping, while the more heavily timbered hilly lands are mainly State Forest reserve producing *Callitris* pine and some fence timber.

Approximately 10,000 square miles were mapped on the broad-scale regional survey of the Brisbane Sheet during the year, bringing the total coverage to 13,000 square miles—about one-third of the area. The soils are being mapped in patterns of major groups. Map symbols carry letter qualifications indicating associated topography and, where applicable, surface texture and soil reaction variation within soil groups. The survey will provide a broad inventory of soil resources in an area where climate generally favours development and will serve as a starting point for more detailed studies. The greater part of the agricultural potential of the State is in this area which includes soils of most of the important Queensland groups.

Another group of soils has been studied and sampled for laboratory analysis for officers of the Division of Plant Industry. Those related to ecological studies in the coastal lowlands are generally similar to soils previously examined from that area. In the Rodds Bay area—part of one of the drier sections of coastal Queensland—solodized soils were again found with some shallow prairie-like soils and small areas of dark clay soils related to the black earths.

3. Soil Chemistry.

(Division of Soils.)

(*a*) *Micronutrient Metals and Their Availability to Plants.*—Progress has been made with this investigation and evidence of the suitability of disodium calcium versenate as an extractant of divalent manganese in soils has been published. Further evidence has also been obtained of the existence of organic complexes of the metals of the first transition series in many organic soils.

Pot experiments with a neutral fen soil from Rendelsham have been directed to determining the relative availability, to oats, of manganese as the sulphate and in the form of three precipitated oxides. This soil is particularly deficient in available manganese. An application of manganese sulphate at the rate of 5 cwt. per acre is the minimum amount necessary to prevent the appearance of manganese deficiency in oats. The oxides used had the approximate compositions Mn_2O_3, Mn_3O_4, and MnO_2 and had the structures of manganite, hausmannite, and manganous manganite respectively. All the oxides proved effective sources of manganese for oats growing on this soil at its natural pH of 6.5 and were superior to the equivalent amounts of manganous sulphate. However, when the soil was limed to pH 8.4 before mixing with the oxides, only the manganous manganite retained its high availability. Crop analyses have indicated that this oxide is consistently better as a source of manganese for oats than equivalent amounts of manganous sulphate.

Since all three oxides examined were available to oats at pH 6.5 it was curious that the response to manganous sulphate was so much poorer under the same conditions. Extractions of the soil with disodium calcium versenate in the presence and absence of a reducing agent have shown that the added manganous

sulphate is readily oxidized in the soil and there is no evidence, from the reactivity of the product of oxidation with the extracting reagent, that it is poorly dispersed.

(*b*) *Rainwater Studies.*—The examination of rain water samples collected in conjunction with the South Australian Department of Woods and Forests and the Soil Conservation Authority of Victoria has been continued. Experience in the collection of rainwater in Victoria has shown the desirability of restricting the samples to monthly rather than longer periods, although this has necessitated a reduction in the number of sample sites. This survey will need to be continued for several years, but already it is showing a number of interesting changes in the amount and nature of the salts in the rainfall, both in regard to location and season.

The composition of the rain falling on an area of subtropical forest, just south of the Queensland border, is being examined and compared with the composition of the river water leaving the area. An estimate of the loss of cations should give some useful information on the weathering and leaching of cations from the forest soils of the area.

(*c*) *Climatological Studies.*—An assessment of the potential evapotranspiration is essential in order to calculate the average amount of rainfall available for soil leaching. During the year a method has been developed which will enable the potential evapotranspiration from normal monthly mean and minimum temperatures to be approximately calculated. This makes it possible to extend the calculations of Prescott to meteorological stations which do not keep relative humidity records, and to check values derived by other methods.

Calculations of the average amount of rainfall available for soil leaching, based on the balance between rainfall and potential evapotranspiration, have shown satisfactory agreement with the major soil boundaries in South Australia.

(*d*) *Spectrochemical Investigations.*—A series of samples taken from a small area of apparently uniform Urrbrae sandy loam was examined and it was found that the sampling error of a single sample was about 10 per cent., in comparison with which the spectrographic error was small. It was also found that the concentrations of the six elements investigated, copper, gallium, magnesium, manganese, molybdenum, and vanadium, were correlated. The trace element status of fourteen other red-brown earth profiles from the Barossa Valley is now being examined to determine the normal variability within the group within a restricted geographical region.

A considerable amount of time has been devoted to improvements in the precision of spectrochemical techniques. A study of the emission of arc and spark lines by manganese, in samples of plant ash with different proportions of potassium and calcium, has shown that the influence of major components on emission by minor components is much more complicated than has been suspected. It is clear that general statements about the influence of major components of a mineral powder on the emission by minor components cannot be made. Each spectrographer must determine for his samples the variation in relative concentrations that can be tolerated without serious loss in accuracy in the determination of each minor component.

Work on the analysis of the total spectrographic error has been continued. It is now clear that the two major sources of variation are fluctuations in the arc column itself and irregularities in the rate at which the sample leaves the electrode to enter the arc column.

More precise results are obtained in the metallurgical field by using an element present in the sample at a constant concentration, the internal standard element, to measure variations in the source of excitation. A study of internal standardization in the arc excitation of plant ash and soil has shown that there is no real gain in precision in the analysis of these materials unless the element to be determined and the internal standard element leave the electrode containing the sample in the same manner. This seems to be the case in practice only when the two elements have very similar chemical and physical properties.

The effect of controlling the arc current during the excitation of mineral powders is being examined. A mechanical calculator, for the correction of line intensities for the effect of background, has been designed and constructed.

(*e*) *Pedological Studies.*—Work is in progress on the interrelationships of the solonchak, solonetz, solodized solonetz, and solod soils. These soils occur throughout the upper south-east of South Australia and the western districts of Victoria. A number of profiles have been sampled and the normal range of variation for several soil chacteristics within any one profile is being determined.

The chemical work associated with the distribution of soluble salts in profiles of Riverina clay, with respect to space and time, has been nearly completed.

(*f*) *Improvements in Methods of Soil Analysis.*—A study of the ethylenediaminetetra-acetate titration for calcium and calcium plus magnesium disclosed that the accuracy generally obtainable by all observers in the titration of calcium plus magnesium was highly satisfactory using eriochrome black T as indicator. The titration could be carried out satisfactorily in either aqueous or ammonium chloride extracts of soils. The results obtained in the titration of calcium only, using murexide as indicator, were somewhat more variable and showed a tendency towards low results in the presence of large amounts of magnesium, unless the alkalinity was very closely controlled. This was thought to be due to the co-precipitation of calcium with the precipitate of magnesium hydroxide. A modified technique was evolved which permitted the accurate titration of calcium with less critical control of the alkalinity.

Phthalein purple (phthalein-complexone) has been found to be a sensitive indicator for alkaline earth and magnesium ions.

The ethylenediaminetetra-acetate method has also been found satisfactory for the determination of small amounts of sulphates in soils, provided a small but sufficient excess of barium chloride is used to ensure complete precipitation.

Simple flame photometers have been further examined. Conversion to sulphates reduced the error due to calcium in the determination of sodium. The use of a good interference filter, in place of the usual gelatine filter, has further reduced the error to an almost negligible amount.

(*g*) *General.*—Samples examined have included soils from the North Australia survey, from New Guinea, and from Norfolk Island. It has also been possible to undertake more specialized determinations to assist in characterizing soil types. Detailed studies have been made of the particle size distribution in some depositional layers of Riverina soil profiles, the proportions of calcium and magnesium in carbonate horizons of soils, and the iodine content of soils. Complete analyses have been made of a number of mineral specimens. Much chemical work was also carried out in following the changes in a soil used for rice-growing at Deniliquin. Assistance has also been given to the Oenological Research group on the use of ion-exchange resins in the removal of cations and anions from wines.

(*h*) *Western Australia.*—In connexion with the study of lateritic soils, further clay separates have been prepared. Silicate analysis has been carried out on these, while the identification of the dominant clay

minerals has been continued by the Physics Department of the University of Western Australia. Free ferric oxide has also been determined in the original soil samples and the clay separates, while the spectrographic analyses of the gravels and fine earths were carried out in the head-quarters laboratory at the Waite Institute.

Routine analysis of the samples from the soil surveys has continued and it is now possible to handle the whole of the samples from the region. Periodical analysis of rainwater samples has continued to ascertain the composition and amount of dissolved salts reaching the soil from the atmosphere.

(*i*) *Queensland Region.*—The studies on the N status of black soils on the Darling Downs have now been completed. The final year's work has confirmed the earlier suggestion that considerable quantities of mineral N are released on ploughing up. This fraction suffers additional losses by leaching. It has also been found that the markedly decreased nitrifying potential in these soils, measured by the percolation technique, is probably caused by increasing alkalinity with depth. This appears to repress the activity of organisms oxidizing nitrite to nitrate.

Following routine observations on samples from a ground-water podzol in the coastal area of south-east Queensland, it was found that the organic matter which accumulated in the B_2 horizon was stabilized by aluminium. A new technique of separating this organic material from the soil, in a form relatively free from metals, has been devised and used successfully on samples from organic horizons of similar profiles from Scotland and New Zealand. Further work is now in progress to find the manner in which iron and aluminium are bonded to the organic fraction in these soils, by using an electrometric titration method developed by the Division.

(*j*) *South-eastern Region.*—The major research project in chemistry is directed to a study of the compounds of phosphorus with iron and aluminium. In non-calcareous soils the larger part of the phosphorus in the soil occurs in combination with these metals. Phosphates of iron and aluminium are being synthesized under different conditions and the effects of these conditions on chemical composition and mineralogical structure are being studied.

4. Soil Physics.

(Division of Soils.)

(*a*) *Water Content of Soil.*—There is a need for methods of measuring water content of soil without resort to sampling. If a source of fast neutrons is placed down a hole the degree to which they are slowed down and scattered by hydrogen atoms in the soil will give a measure of the water content. Apparatus for measuring water content on this basis has been built up. Results are highly reproducible and the method shows much promise. It is not accurate at shallow depths of a few inches because of the escape of fast neutrons but its accuracy at greater depths is very satisfactory. A theoretical basis for calibrating this instrument (water content in relation to counts) has been developed. This should help the calibration of any new instruments. Without this help it is necessary to have access to large volumes of soil of uniform water content for the purpose of calibration. Using this method, a comparison is being made with values for potential loss of water from soil by transpiration calculated from meteorological data. The comparison is valid only when the soil has ample water so that rate of transpiration is not restricted and hence does not fall very materially below that expected from meteorological data.

(*b*) *Permeability of Soil.*—As a result of work previously reported, information has been obtained on movement of water in unsaturated soil with and without a temperature gradient. An attempt is now being made to measure permeability of unsaturated soil by using columns from which water was allowed to evaporate from one end. The method used required sampling a number of identical soil columns at different intervals of time to determine the rate of loss of water in relation to water tension gradients. The accuracy of results was limited by the degree to which a number of soil columns could be made identical in water content and density. To overcome this a technique is being developed in which measurements are done on a single column of soil in which a constant rate of loss of water is maintained by evaporation at one end and by supplying water under tension at the other end. The tension gradient along the length of the soil column is measured by small tensiometers and calibrated gypsum blocks.

(*c*) *Swelling.*—Relations between volume of soil, water content, and tension of the water in swelling and shrinking soils have been determined under laboratory conditions. Hysteresis occurred in each wetting and drying cycle in the relation between the water content and tension of the soil water. This was considered to be due to the internal rearrangement of particles accompanying change in volume. The effect of salts on swelling of soil is at present under examination.

(*d*) *Effect of Electrolyte Concentration.*—Some preliminary work has been carried out at Deniliquin, New South Wales, on the effect of electrolyte concentration on entry of water into saline soil containing an appreciable proportion of exchangeable sodium. These results indicate that initially there is very little difference in the amount of water entering the soil when 10 mg. equiv. of calcium chloride are added to each litre of irrigation water as compared with the irrigation water alone which contained only 0.5 mg. equiv. per litre. It is considered that there were sufficient salts present in the soil to keep the colloids in a flocculated condition. The work was carried out on other soils with appreciable exchangeable sodium and similar results were obtained. This work is to be continued.

(*e*) *Relation of Free Iron Content to Structure.*—In the course of an examination of the physical properties of terra rossa and rendzina soils a close relation was noted between the free iron content and the volume occupied by large pores (macroporosity). Macroporosity was found by measuring total porosity at 100-cm. tension by means of a method developed in this laboratory and by using water content at this tension. Water stability was measured by wet sieving. There is a high correlation between macroporosity and free iron oxide associated with the clay in these soils, even though the organic matter contents differ considerably. It would appear, however, that high organic matter increases macroporosity. This factor tends to separate these soils into two groups on macroporosity values, the macroporosity of the rendzinas (higher organic matter) being greater than that of terra rossas at the same level of free iron oxide.

(*f*) *Stability of Aggregates.*—The effect of water content on the mechanical stability of soil aggregates is being examined. The air-dry aggregates from cultivated soil, although having a similar texture and porosity as those from virgin soil, break down completely when placed in water whereas the virgin aggregates are completely stable. The virgin aggregates have a greater mechanical strength at all soil water contents. An additional factor is that when air-dry aggregates of each soil are wetted under a tension of 10 cm. of water suction, the cultivated aggregates wet much more rapidly and wet to a water content which exceeds the initial porosity. This aspect is being studied.

The initial tension of the soil water has an effect on stability of soil aggregates in water. It has been found that even unstable aggregates (5-10 mm.) are completely stable when immersed in water if previously wet at a soil water tension of 100 cm. At conditions wetter than 100-cm. tension, there is a decrease in stability which is attributed to incipient failure resulting from rapid wetting. The break-down of aggregates when drier than 100-cm. tension is brought about by differential swelling and disruption due to entrapped air.

(*g*) *Surface Sealing of Soil by Rain.*—The mechanism of formation of thin seals on soils under heavy rain has been investigated using a red-brown earth. Some field measurements have been made but most of the work has been carried out in the laboratory under simulated rainfall. A technique has been developed for measuring permeability of these seals which are of the order of $^1/_{10}$ mm. thick. Using this technique and measuring permeability under various conditions it has been found that seals on an unstable cultivated soil have much lower permeability than those on a virgin soil newly cultivated. The seal formed on the poorly structured soil after heavy rain has a permeability whose value is of the order of one two-thousandth of that of the underlying soil. Investigation tends to show that washing in of fines does not ordinarily proceed further than the $^1/_{10}$ mm. from the surface, and that compaction of this surface by drop impact and the orientation of clay and silt at the surface are the dominating factors in lowering permeability.

(*h*) *Soil Structure, Crusting, and Germination.*—Investigations into the effect of structure decline and surface crusting under heavy rains show that the poor germination of wheat under these conditions is most probably a result of lack of air. The effect was much worse in a fallow-wheat rotation than in a fallow-wheat-peas-pasture rotation, and crusting on the former was considerably greater than on the latter. Crusts formed had almost zero pore space available for air at field capacity and under the wet conditions that prevailed at the time it seems likely that diffusion of air to seed and root depth was prevented.

(*i*) *General.*—The Division has continued to assist other research groups in and out of the Organization with measurements of physical properties of soils and advice on equipment for work in soil physics. There has been a notable increase in the number of Australian laboratories which are now becoming equipped for work in this field.

(*j*) *Queensland Region.*—(i) *Physical Properties of Soils.*—The routine characterization of survey samples has been continued and an examination of the data made to test the application of an index to express the physical status of the soils. A general statement covering the physical properties of the Burdekin Valley soils and their influence upon development for irrigation has been prepared.

Further investigation of several of the laboratory methods associated with physical analysis has been made with the aim of establishing quick, reliable methods for soil characterization. The measurement of particle density has been re-examined and the density of the common soil components such as iron oxide and organic matter has been measured. The real density of the different fractions of organic matter has been found to differ considerably, and the density determination appears to be an aid in the identification of these fractions.

Studies have been made upon a group of soils from the coastal lowlands of south-east Queensland. Most attention has been devoted to the fragipan which occurs in ground-water podzols. These extremely dense pans have been shown to result from simple packing of the quartz grains which in these horizons extend into dimensions of the clay fraction. The permeability of the pans which cause waterlogging of the surface horizons has been measured by using gas and liquid methods. Further work on these lines is proceeding.

(ii) *Structure Alteration in Cultivated Soils.*—Comparison of virgin grassland and cultivated soils from the Darling Downs, referred to in the previous Report, has shown differences in aggregation between the two conditions. The significance of these results in relation to husbandry has yet to be determined. One difficulty with these soils is the lack of a suitable method of structure assessment. Considerable effort with promising results has been devoted to development of a method based on the properties of compressed blocks of the soil material compared with those of naturally occurring aggregates.

(iii) *Water Content Changes in Natural Soils.*—Regular observations have been continued on the joint project being conducted with the Ecology Section, Division of Plant Industry, concerning soil moisture. It appears that a considerable period will be required to establish definite trends in the microhabitat conditions for the different plant communities. The range of sensitive moisture determinations will be extended by the projected installation of tensiometers which will allow the moisture fluctuations during the wetter months to be followed. Suitable instruments are still being acquired and installed to define the general hydrology of this small watershed. A stream gauge to measure discharge should be in operation shortly. Regular sampling of rainfall and run-off has been commenced for analysis by the Soil Chemistry Section, Adelaide.

(*k*) *South-eastern Region.*—The soil physics laboratory is now equipped for measurements of physical properties of soils of this Region, and staff is being built up on a long-range plan. Water relations and structure of a number of soils have been examined in relation to soil survey activities and to assist the Commonwealth Research Station, Griffith, New South Wales.

In addition the effect of rice-growing on structure of soils was examined in co-operation with the Soil Survey Section. No definite increase in stability of structure with increasing period under rice culture involving nil to eight crops was found in the samples taken on selected farms. Assistance was also given to a study of the effect of electrolytes on infiltration of water into soil at Deniliquin, New South Wales. (*See* (*d*) above.)

5. Soil Microbiology.

(Division of Soils.)

(*a*) *Phosphates and Soil Microorganisms.*—Work has continued on the influence of the availability of phosphatic minerals upon the respiration of the soil microflora. A number of natural and synthetic phosphates were checked by X-ray analysis, then bioassayed for available phosphate. The availability of the minerals can be divided into three main classes, viz.:—

(i) *Readily Available Phosphates.*—Those containing iron—amorphous ferric phosphate and an unnamed mineral isostructural with Haseman's product P; those containing aluminium—amorphous aluminium phosphate and metavariscite; those containing potassium and iron—two unnamed minerals isostructural with Haseman's products D and L; and those containing potassium and aluminium—taranakite and a lower hydrate of taranakite.

(ii) *Fairly Available Phosphates.*—Those containing iron—an unnamed mineral isostructural with Haseman's product P; those containing aluminium—an unnamed mineral isomorphous with metastrengite; those containing ammonium and iron—hydroxyminyulite and an unnamed mineral isostructural with

Haseman's product F; and those containing potassium and iron—a coarsely crystalline, unnamed mineral isostructural with Haseman's product L.

(iii) *Poorly Available Phosphates.*—Those containing iron—strengite; those containing aluminium—variscite and berlinite; those containing potassium and iron—leucophosphite; those containing potassium and aluminium—hydroxyminyulite, fluorminyulite, and two unnamed minerals isostructural with Haseman's products C and S; and those containing ammonium and aluminium—hydroxyminyulite and an unnamed mineral isostructural with Haseman's product G.

In general, finer particles of a mineral were better sources of phosphate than coarser particles. Usually phosphates were more available from iron than from isomorphous aluminium minerals. Sands devoid of phosphates or containing poorly available phosphatic minerals promoted only slight initial respiration. The low activity thus indicated often became quite high after approximately 10 days' incubation at 25° C. and suggested that certain microorganisms developed with extremely low phosphate requirements.

Studies were made in sand of the availability of phosphates from good sources, such as potassium dihydrogen phosphates and iron phosphate (isostructural with Haseman's product P); from a fair source —variscite; and from a poor source—variscite.

The experiments were made at pH 4, pH 6, and pH 8. The mixtures were incubated for periods up to five weeks at 25° C. in the presence and absence of the phosphate fixing agents, amorphous aluminium hydroxide, kaolin, and calcium salts. In general respiration was greatest at pH 8 and least at pH 4 with potassium dihydrogen phosphate and variscite; but often the reverse occurred with iron phosphate and apatite. Usually aluminium hydroxide fixed more phosphate than either kaolin or calcium salts, which sometimes caused no fixation. With potassium dihydrogen phosphate, fixation was greater after five weeks than after no incubation but with the other three minerals fixation varied depending on conditions.

(*b*) Rhizobium *Studies.*—Studies have begun on the antigenic components of rhizobia associated with various pasture and indigenous legumes. Methods of production of antisera in rabbits have been tested in order to obtain stable sera of high titre suitable for cross-agglutination tests of strains and species. Such sera have been used to follow the fate of strains of subterranean clover rhizobia inoculated into soil containing indigenous forms. Some strains of rhizobia are useless for commercial cultures owing to their inability to establish themselves effectively in competition with indigenous forms over consecutive seasons.

A cytological study of strains from all the commonly accepted species of *Rhizobium* has revealed considerable variability of colony characters and cell morphology. An undescribed rough (R) form of growth produces endospores under appropriate conditions, but these variants have not yet been tested for their ability to nodulate legumes and fix nitrogen.

(*c*) *Fractionation of Soil Humus.*—Further attempts have been made to isolate proteins from humus extracted from peats and soils, but without success. A large continuous electrophoresis apparatus has been built to obtain sufficient quantities of humus fractions for chemical analysis.

The changes in plant proteins have been followed during their decomposition in the presence and absence of humates and lignates. Soluble proteins were no longer detectable by the sensitive brom phenol blue dyeing method after about one month's incubation at 25° C., irrespective of the presence of possible protein-trapping substances in humates and lignates.

(*d*) *Oxidation of Hydrocarbons by Soil Bacteria.*—Work has continued with the same soil bacterium used previously, now identified as a Corynebacterium sp.

R.Q. values, obtained by using Warburg respirometers, for the oxidation of *n*-hexadecane, *n*-tetradecane, and *n*-decane indicate their complete oxidation. Increased dispersion of *n*-decane by surface-active agents did not increase its oxidation rate, but homogenizing in a blendor increased the rate fivefold.

The organism oxidizes *n*-fatty acids (C_1-C_{10}), *n*-fatty alcohols (C_2-C_{11}), several aliphatic aldehydes, and the higher methyl ketones. It is unable to oxidize the lower ketones or cyclic compounds. Co-oxidation rates of *n*-decane with its oxidation derivatives show no summation of the respective individual rates, indicating that common group specific enzymes are involved at some stage in the decomposition.

The oxidation of *n*-decane is unaffected by malonate in concentrations which caused 50 per cent. inhibition of the oxidation of succinate. *n*-Decane oxidation is inhibited 75 per cent. by 0.004M fluoracetate, 100 per cent. by 0.008M cyanide, 90 per cent. by 0.12M azide, 100 per cent. by 0.0001M mercuric ions, and 88 per cent. by 0.0008M iodoacetate. In reverse 0.008M cysteine completely reactivates cells inhibited by iodoacetate. Two non-volatile acids, chromatographically identical with lactic and glutaric acids, are produced during the oxidation of *n*-decane. No volatile acids were detected.

Work has started on the comparative ability of fresh and lyophilized preparations of the bacteria to oxidize *n*-decane and its oxidative derivatives. The rate of oxidation of *n*-decane by freeze-dried cells rapidly falls on aging them at 4° C., but can be raised by adenosine triphosphate or by monovalent cations, especially potassium.

6. Clay Mineralogy.

(Division of Soils.)

During the year a new four-windowed X-ray set was installed and another powder camera and a diffractometer have been put into use. Suitable electronic Geiger counting equipment has been built up for use with the diffractometer and spectograph.

(*a*) *Phosphate Minerals.*—For the past two years a study has been made of phosphates which are likely to occur in soils. The work has been carried out in co-operation with the Soil Microbiology and Soil Chemistry Sections which are interested in the forms of phosphate in the soil and the mechanisms of phosphate fixation. A major problem in this work has been the obtaining and certifying of pure minerals on which to work. Some museum phosphate minerals are mislabelled, and incorrect and insufficient published data make identification very difficult. Some 150 phosphates have been studied by X-ray diffraction techniques and 30 pure mineral certified. Apart from fulfilling local needs this study should be useful in straightening out much of the confusion in identifying phosphates. To aid this purpose, much of the diffraction data which is original is being sent to the Institute of Physics for inclusion in the A.S.T.M. Crystallographic Index.

During this study a new aluminium phosphate mineral was discovered. Chemically the mineral differs from other known aluminium phosphates, wavellite, sterrettite, &c., in being highly hydrated (39 per cent. water), and it is decomposed at a relatively low temperature, 120° C. A crystallographic study, which is almost finished, shows it to be a distinct mineral species.

(*b*) *A Soil with Unusual Water Relations.*—In co-operation with the Soil Physics Section a detailed study was made of an unusual soil from Tintinara, South

Australia. This soil, which had a clay content of only 25 per cent., had a wilting point of 30 per cent. as measured in a pressure membrane apparatus. The wilting point of most soils of this clay content would not exceed about 10 per cent. Measurements of the water content at wilting point of other soils and clays of known mineralogical composition showed that relative to 100 per cent. clay, kaolin, illite, and montmorillonite have values of 35, 40, and 60 per cent. respectively. This figure for the fibrous minerals sepiolite and palygorskite was much larger—90 per cent. X-ray analyses showed the clay of the Tintinara soil to be sepiolite. The fibrous and exceedingly small particles accounts for the very high wilting point, 120 per cent. relative to the clay content of the Tintinara soil. This is the first time sepiolite has been recognized in a soil. This sepiolite is unusual in that it contains appreciable aluminium.

(*c*) *Soil and Clay Analyses.*—In conjunction with a soil survey, a detailed mineral analyses have been made of soils from the Eastern Scarp to the Darling Downs, in the Toowoomba area. It is hoped that these analyses will aid in the interpretation of the field behaviour of the soils and in distinguishing relict from modern soils.

Analyses of soils from New Guinea, at the request of the Land Research and Regional Survey Section, show that some soils are highly weathered while the mineral assemblage of others indicates very young soils. All the soils reflect the continuous wet and humid conditions in the frequent occurrence of hydrated halloysite. This is a mineral which would be irreversibly dehydrated in most areas of Australia.

In conjunction with the work of other Sections and the various regional groups of the Division, clay mineral analyses have been made of soils from the following areas: Norfolk Island, Capel-Boyanup (Western Australia), the coastal lowlands north of Brisbane, and Griffith (New South Wales).

An examination of samples from Lake Eyre has shown palygorskite to be present in the dolomite of the lake bed. These samples were examined because it was thought that the conditions at Lake Eyre were those likely to form this clay. The mineral analyses are also of value in aiding Mr. C. W. Bonython, who has been studying the lake deposits, to follow the changes occurring to various salts. The surface salt is pure sodium chloride despite the fact that considerable quantities of calcium, magnesium, and potassium have been introduced into the lake. The mineral analyses show these cations to be present below the surface of the lake as gypsum, dolomite, jarosite, and palygorskite.

(*d*) *Fluorescent X-ray Spectroscopy.*—The X-ray spectrograph started some years ago was used during the year for various chemical determinations. Its operation had been delayed pending the obtaining of suitable crystal holders. A Geiger counter was fitted to the instrument to replace photographic techniques. All elements of atomic number greater than titanium can be determined, but so far the theory and techniques for quantitative determinations in soil have been developed for only titanium, manganese, and iron. The latter elements can be determined with an error of about 5 per cent. of the amount present, with a single count of several minutes. No pretreatment, other than light grinding, is involved. The accuracy can be improved by the incorporation of internal standards. The determination of small amounts takes longer, about 30 minutes counting for 100 p.p.m. of manganese or iron, and at present this concentration is regarded as the lower practical limit. The method can be applied to many other elements and the techniques for these will be developed when required.

7. Soil Mineralogy.

(Division of Soils.)

South-east Region.—Over the past three years work in the Canberra Laboratory on the mineralogy of soils has progressed by petrographic methods. A very full study has been made by mineralogical and thin-section techniques of a yellow podzolic soil formed on granodiorite. These show a progressive increase in weathering of all primary minerals from the deepest horizon to the surface. There is also less clay in the finest-textured layers than would have been formed by the degree of weathering observed for the primary minerals originally present. Both from the above observations and from the orientation of the clay shown in thin sections it is considered that clay illuviation did not occur to produce these horizons.

Later work dealt with a petrographic study of two red-brown earth profiles in the Murrumbidgee Irrigation Areas wherein their nature was demonstrated to be due to clay illuviation in one case and wind-blown accession in another. The correlations between soil origin and profile genesis by the techniques now developed provide a new and useful approach quite promising for such studies.

Many soils show siliceous remnants of sponges and diatoms which could not exist alive in them under present climatic conditions. Their distribution in south-eastern Australia has been studied and it is postulated that the remnants are not, as was previously thought, largely wind-blown accessions, but have been produced *in situ* under a moister climatic cycle favouring growth of the organisms in Recent times, possibly after the last arid period.

8. Soil Mechanics.

(Division of Soils.)

(*a*) *General.*—During the year the subject of soil mechanics has received recognition by establishment as a separate section of the Division. Although, in the past, some attention has been given to this subject both within the Division and in the Universities and Government Departments, there has been a growing awareness of a need for research and investigation on a broader front than hitherto.

The principal focus of attention within the subject of soil mechanics, as it affects engineering development in Australia, is now upon problems of a regional character. It has been shown that soil conditions exert a major control over the development of important areas of the population centres of Australia. A preliminary survey of these regional problems has been made to define the basic nature of the soil properties controlling building development, the areas affected, and the ability of the building industry to support financially an appropriate investigational programme. In almost all cases it has been found that the complexity and expense of a complete soil investigation is such that it cannot be justified as a charge against an individual building; whereas the same investigation set against the total building programme of any region appears as an insignificant cost.

A total of ten such regional problems has been recognized in the States of Victoria and South Australia. For the present, attention is being directed to two principal regions—the Para block area adjacent to Adelaide and the South Melbourne region, Victoria. Information is being recorded for the other regions as opportunity offers.

(*b*) *Foundation Characteristics of the Soils of the Para Block Area.*—In this area with an extremely complex pattern of soils there has occurred the most troublesome series of foundation failures recorded in South Australia. The pattern of soils is such that

any one building may rest in part on a saturated granular material (with some clay), in part on a drained granular material, and in part on a heavy clay which is high in exchangeable sodium. Within one building site therefore the soil characteristics are such that bearing capacity values of almost zero to very high values may be determined; settlements under equal loading conditions may be negligible to very high; and volume change due to seasonal changes of water content may also be negligible to very high. A quantitative expression is being sought for each of these soil properties to facilitate foundation design.

(*c*) *Strength Characteristics of Unsaturated Soils.*—Unsaturated soils are a characteristic of the Australian environment but the engineering properties of such soils have received little attention in the traditional studies of soil mechanics. A preliminary attempt is now being made to define these properties. Three stages of the project have been attempted so far: 1. The definition of the conditions of unsaturation in zonal soils of the Australian environment. 2. The measurement of the influence of specific conditions of moisture stress and pore space saturation on the strength of granular materials tested under conditions of controlled moisture tension. 3. The measurement of the influence of specific initial conditions of moisture stress and pore space saturation upon the undrained shear strength of clays.

9. Earth Auger.

(Central Experimental Workshops.)

The normal process of soil sampling employed by the Division of Soils in survey work involves considerable manual effort, insofar that holes are bored with a hand-operated auger, frequently to the depth of several feet. With the conventional auger head, samples are taken at 4-inch intervals, and with a 4-inch diameter auger considerable force may be required to withdraw the auger and sample from the hole.

With the object of simplifying the sampling operation, particularly on the deeper holes, a power-driven earth auger has been developed for the Division. It is mounted on a two-wheeled trailer for towing behind a utility truck, and the power is supplied by its own 6 horse-power petrol engine. The auger itself is driven by a hydraulic motor, and is also removed from the hole hydraulically, the maximum depth of hole which can be dug being 10 ft. 6 in. The machine has been given a thorough trial in service in the Griffith area and has been found to meet the design requirements very successfully. A description of it is given in Central Experimental Workshops Internal Report No. 15, entitled "Power-Driven Earth Auger" by I. P. Arthur (1954).

III. PLANTS.

1. General.

Plants, whether in the form of crops or pastures, are the basis of every agricultural industry, and viewed in perspective grass is Australia's most important primary product. The Organization has placed considerable emphasis on investigations of plant problems at the Division of Plant Industry, which has its headquarters in Canberra and is the Organization's oldest Division. The work of the Division, which has experimental farms and field stations throughout the Commonwealth, is described in this Chapter.

Allied work on mineral nutrition of plants carried out by the Division of Biochemistry and General Nutrition is described in Section 11 of this Chapter.

Work on special local problems of irrigation districts is undertaken by the Irrigation Research Stations at Merbein and Griffith (*see* Chapter IV.).

The Division of Entomology is carrying out work on weed control, insect pests of pastures and crops, and insect vectors of virus diseases (*see* Chapter IX.).

The Land Research and Regional Survey Section is carrying out broad-scale ecological surveys in the under-developed, arid and semi-arid regions of the continent to assess their land-use potential and investigate problems of agricultural and pastoral development. The work on these regional surveys is reported in Chapter XI., Section 2, and the Section's investigations on crops, fertilizers, plant diseases, tillage, and native and introduced pastures under dry-land cultivation at the Katherine Research Station, and under irrigation at the Kimberley Research Station, are reported in Chapter XI., Section 3 *et seq.*

Research on biophysical aspects of plant growth is being undertaken at the Physics Department of the University of Tasmania and is reported in Section 23 of this Chapter.

The research of the Plant Fibre Section on fodder conservation is reported in Section 24 of this chapter, and the evapotranspirometer and the nursery thresher designed and constructed by the Central Experimental Workshops are described in Sections 25 and 26 of this Chapter.

Division of Plant Industry.—The research work of the Division is concentrated on problems which are fundamental to agricultural production in Australia. In this it is complementary to the activities of the State Departments of Agriculture, whose particular function it is to serve the more immediate needs of the agricultural industries.

Because of the great importance of pastures in the Australian economy and also because of the difficulties of establishment, utilization, and maintenance of improved pastures, many of the Division's activities directly or indirectly serve the pastoral industries of the Commonwealth. However, research work on other crops of economic importance which require a particular effort in their introduction, establishment, or management, is included in the programme. Agronomic and agrostological research is thus the first line of the Division's activities. Complementary to this work studies are in progress of a more fundamental nature designed to contribute to general knowledge of plant life and plant production.

During the year there has been further development of the research programme outlined in last year's Report. This has been mainly due to the appointment of eleven new research staff in the fields of plant chemistry, biochemistry, biophysics, genetics, microbiology, agronomy, and pasture utilization. Particular reference is made to the appointment of a senior biochemist in Canberra and of an officer stationed in Queensland to commence an intensive programme of regional agronomic trials under the personal supervision of the Associate Chief.

To further the work in south-eastern Queensland the Division has acquired 200 acres at Samford, near Brisbane, which will be used as the experiment station for the Queensland regional laboratory at Brisbane. A grant has been received from the United Graziers' Association in Queensland for the purchase of a small herd of Hereford to be used for cattle grazing trials at Samford.

The Division has been a party to the establishment of a research committee to direct the work of the Regional Pastoral Laboratory at Armidale in order to ensure effective collaboration there between the staffs of the University of New England and C.S.I.R.O.

Officers of the Division have been honoured by invitations to attend overseas scientific conferences.

The Chief of the Division, Dr. O. H. Frankel, was invited by the organizers of the Cold Spring Harbour (New York) 20th Symposium on Quantitative Biology

to attend the symposium on population genetics. This visit to the United States was aided by a grant from the Carnegie Corporation of New York.

Mr. A. J. Anderson accepted an invitation by the Johns Hopkins University to present a paper at the McCollum Pratt Symposium (Baltimore, United States of America) on nitrogen metabolism.

Miss N. T. Burbidge, who recently returned from Kew, United Kingdom, where she was stationed for two years as Australian Visiting Botanist, attended the International Botanical Congress in Paris as an official Australian delegate.

Both Mr. R. W. Prunster, Officer-in-charge at Deniliquin, and Mr. R. W. Jessup, ecologist who is visiting the United States on a Smith-Mundt Fellowship and a Rockefeller Travel Grant, attended the Arid Zone Conference organized by U.N.E.S.C.O. in New Mexico.

Mr. W. Bryan, agronomist, Brisbane, was a member of a South Pacific Commission survey team on the productivity of grasslands in the tropics and visited New Guinea, New Caledonia, and Fiji.

The Division was associated with the organization of three Conferences during the year. A plant introduction conference in Canberra held under the auspices of the South Pacific Commission was attended by representatives from Papua and New Guinea, Fiji, India, Noumea, and the United States. Under the auspices of the Australian Agricultural Council a weed control conference held at Roseworthy, South Australia, and a plant diseases conference held at Hawkesbury, New South Wales, were attended by representatives of Commonwealth and State Government Departments and universities.

The Division continued to provide both long- and short-term specialized training to holders of F.A.O. Fellowships and of Fellowships under the Commonwealth Technical Assistance Co-operation Scheme. The Division continued its co-operation with many State and Commonwealth Departments and universities and with overseas organizations. This co-operation is most fruitful and is appreciated.

2. Plant Introduction.

(Division of Plant Industry.)

(*a*) *Plant Exploration.*—A plant exploration mission to the Mediterranean region which has been organized in collaboration with F.A.O. was completed during the year. The main collections consisted of strains of grasses and other pasture plants of potential value to southern Australia, including *Phalaris tuberosa* (97 strains), *Lolium rigidum* (90), *Dactylis hispanica* (100), and *Lolium perenne* (53). The larger collections were made in the North African countries of Algeria, Morocco, and Libya, while smaller collections were made in Portugal, Greece, Cyprus, and Israel. In all 686 collections were made and the seed shared between the Organization and F.A.O. A full account of the collecting mission has been prepared for distribution and publication by F.A.O.

Detailed studies of the principal groups of plants collected have been initiated at Canberra, Perth, and Adelaide.

(*b*) *Agronomic Trials.*—Preliminary trials of new introductions as well as more detailed studies of those which had previously shown promise have been continued at the four primary nursery quarantine stations, and at various subsidiary stations associated with them. Important developments during the year have been the decision to discontinue the introduction trials at Katherine in the Northern Territory, and the transfer of the work at Brisbane to a new station at Samford. The work at Katherine had fulfilled its purpose in providing information about the varieties of various crop plants which are suited to the climatic and other conditions of Northern Australia. Their utilization in a general agricultural pattern will be dependent upon more extensive studies, in which the introduction aspects are not at present of importance.

There is an evident need to assess otherwise promising introduced pasture plants under actual grazing conditions at the earliest possible opportunity. At Canberra some of the most promising introduced grasses have been established in grazing blocks with associated legumes, while at the new Brisbane station some 50 to 60 introductions are being set out for trial in smaller grazing blocks. The supply of seed for trials of this nature is being developed in co-operation with the Irrigation Research Stations.

Several grasses introduced in earlier years are becoming increasingly prominent on a commercial or semi-commercial scale. In Western Australia two strains of cocksfoot of Mediterranean origin have been distributed for extensive trial by selected dairy-farmers, while a strain of *Hyparrhenia hirta* appears to be particularly valuable for the coastal sands. An African strain of buffel grass which was released some years ago through the Education Department in Queensland is now an important commercial plant, especially in the Gayndah district, while *Sorghum almum*, notwithstanding certain objectionable characteristics, has been grown on a large scale in northern New South Wales. Further strains of this latter grass have been introduced with a view to the selection of strains free from toxicity and rhizome development.

Investigations on cereal varieties which occupied an important place in the research programme in Western Australia have been substantially completed. Summaries of the results obtained, especially concerning seed of the best varieties, are being made available to the various Departments of Agriculture.

(*c*) *Plant Growth Studies.*—A large-scale field experiment designed to compare the growth of strains of *Phalaris tuberosa* from many localities in the Mediterranean region has been completed at Canberra. The data obtained will be studied in relation to the climatic and other conditions of the localities from which the sample originated. Similar studies have been continued at Perth, where a comparative study of species of *Trifolium* has also been initiated. It is believed that this may facilitate the selection of strains suited to localities where subterranean clover does not flourish at present.

As part of a long-term programme of investigation of problems of basic importance to plant introduction work in Australia, studies have been begun at Canberra on problems of drought resistance and seasonal dormancy in introduced plants. These are still in the early stages and will involve field, glass-house, and laboratory studies.

Investigation of the problem of seed-setting in species of *Arachis* has not yet yielded positive results. Poor seed-setting is a major problem in many otherwise promising introduced plants, and studies within this general field will be extended.

(*d*) *Plant Geography.*—Work has been completed on a large-scale vegetation map of Australia for inclusion in the Atlas of Australian Resources, and a descriptive brochure prepared. The atlas comprises maps and discussion of economic potential of the nation as related to its primary physical and biological resources. This particular map is concerned with comparative regional ecology as related to plant introduction. It will provide a basis for comparison of Australian vegetation forms with their foreign analogues.

From this map, and in collaboration with the Professor of Botany of the University of Adelaide, a generalized map has been prepared for a revised edition of "The Australian Environment".

(*e*) *Climatological and Growth Studies.*—Considerable attention has been given in the last year to relations between the rate of growth of pasture species and the rate of growth of climatic environment, using principles of harmonic analysis. In particular, objectives are—

(i) to discover the more important elements of meteorological climate associated with changes in the rate of growth of plant species;

(ii) to utilize these elements as a basis of prediction; (1) to define global homoclimes against plotted agricultural and pastoral regions with the objective of narrowing the fields for specific plant introduction research; (2) to define potential zones of distribntion for specified biotypes, climatic races, or species, from the plotting of experimentally determined relationships between genetic material and known Australian environments.

Research has been concentrated initially on phase (i), for once relationships are established phase (ii) becomes rapidly defined in the form of reconnaissance survey.

Phase (i) has been attacked by using methods of harmonic analysis to break relative growth rates of plant material into a group of component sine curves. Relationships have then been sought between those curves and meteorological elements of the locality that are the normal constituents of weather (and the ultimate components of the climate of that area).

Extremely high correlations have been recorded for many species between these sine curves and lagged temperature and the lengths of day and night. Lagged temperature has been used as an approximation to radiation values. More recently, research has been centred on the relation between temperature and the water variables of the atmosphere, and all of these with radiation, with the objective of developing a general formula enabling one to determine radiation values from measured and freely available meteorological variables. Extremely satisfactory curvilinear and linear relationships have been obtained between lagged temperature and some lagged water vapour components of the atmosphere for continent-wide Australian stations and with both mean nightly and mean daily temperatures. Radiation relationships are now being sought against these lagged temperature/water vapour components.

(*f*) *International Exchange.* — International exchange activities have increased very greatly during the past twelve months; the number of introductions received from overseas have quadrupled, and treble the number of samples have been sent overseas in return.

Of the 1,336 plant introductions received from overseas for trial, rather more than half consisted of collections made in the Mediterranean region during the joint collecting expedition with F.A.O. which is dealt with more fully below. Apart from these collections, propagating material was received directly from 37 different countries, the principal contributors being the United Kingdom, the United States, Canada, Sweden and Morocco. Large collections of lucerne strains were obtained for genetical and breeding work which has been begun with this species, while collections of species and strains of *Leucaena*, *Indigofera*, and other genera were obtained for studies of tropical pasture legumes.

The great increase in the number of samples sent overseas was in part due to the fact that F.A.O. and Colombo Plan Fellows working in Australia arranged to take back collections of varieties which they considered might be worth trial in their countries. It was also in part attributable to the fact that during the year a seed exchange list was issued and many requests were received as a result of the distribution of this list. While a heavy burden is imposed upon the staff in dealing with such a large number of overseas requests, the supply of Australian plant material overseas is valuable not only for the goodwill it creates, bnt also because the investigations of overseas scientists may supply useful knowledge about groups of Australian plants. Thus cytogeneticists working in the United States and India have added to our knowledge of the taxonomy of certain groups of Australian grasses.

All the samples received, and those sent in exchange, have been critically examined for quarantine purposes. Special problems which have received the attention of the quarantine officer include the study of methods of treating rice seed to obtain effective disease control without reduction of germination. A study to determine the best method of preservation of *Rhizobium* within nodules was completed.

3. Genetics.

(Division of Plant Indnstry.)

(*a*) *Subterranean Clover.* — The research programmes concerned with subterranean clover aim at the production of strains adapted to be a wider environmental range than is possible with material available at present.

(i) *Hybridization and Natural Selection.* — This programme, aimed at increasing the diversity of species, will be impeded but not prevented by the presence of reduced fertility in the progeny. Rates and direction of change under natural selection are being investigated at twelve locations in New South Wales. Introduced strains from the Mediterranean area and the Canary Islands are being tested for possible use in this programme.

(ii) *Subspeciation.*—This was indicated by reproductive and vegetative anomalies in progeny of crosses between some varieties. Pollen sterility reduced seed-setting, and embryo abortion occurred in the F_1 and F_2 generations while dwarf and semi-dwarf plants segregated in some F_2's. Indications are that the abnormalities are independently determined, and the main cause of sterility appeared to be genic.

The presence of sterility barriers suggests that many varieties were reproductively isolated before they were introduced to Australia. Major varietal differences are unlikely to have arisen from selection of locally adapted ecotypes.

(iii) *Flowering Time.*—Subterranean clover is a long-day plant which requires a certain exposure to low temperatures and a sufficient photoperiod before flowering is induced. Some varieties are late flowering, not because of long or deep cold requirements but because of high photoperiod requirement or slow development of flowers, especially at low temperatures. Thus flowing time may vary between locations. Variation in flowering time appears to be related to mode of induction, those varieties having long cold requirements being most variable.

(iv) *Seed Dormancy.*—There are clear differences between varieties in speed of germination of imbibed and refrigerated seeds. The lack of suitable techniques to counter stimulation by carbon dioxide is a problem in this investigation.

(v) *Seed Yield.*—Heritability of seed production and comparisons of single plant and sward seed production are being investigated.

(*b*) *Other Legumes.* (i) *Lucerne.* — An extensive hybridization and natural selection programme nsing *Medicago sativa* and *M. falcata* is in progress. The

aim is to produce improved irrigation and dry-land types of lucerne. Preliminary results indicate rapid selection for shorter-day length requirements. A technique has been developed for vegetative propagation which will be used in clonal testing.

(ii) *Annual Medics.*—Inheritance of burr structure and hard seededness in annual species of *Medicago* is being investigated. Both these characters are important in relation to the agronomic usefulness of the species.

(iii) *White Clover.* — Differences in self-compatability, which may have evolutionary significance in subspecies formation, have been found among populations originating from various parts of Europe. The frequency of white leaf markings controlled by a single gene in different populations has been established in a number of European and Asian populations. Gene frequencies for this character are correlated with those for the production of the cyanogenetic glucoside lotaustralin and of the enzyme liberating hydrocyanic acid, linamarase.

(*c*) *Grasses.*—(i) Danthonia (*Wallaby Grass*).—Cytogenetic and cytotaxonomic studies of *Danthonia* species are being made to provide basic information necessary to evaluate the prospect of improving the agronomic usefulness of these native grasses.

Preliminary investigations have revealed chromosome numbers within the genus ranging in a polyploid series from 2n = 24 to 2n = 120. Although the genus *Danthonia* is in general cleistogamous, and consequently self-fertilizing, several hybrid plants have been collected in the field. Further studies are aimed at assessing the extent and significance of cross-pollination within the genus and the relationships between the various species.

(ii) *Phalaris.* — Cytogenetic studies on various species and interspecific hybrids of *Phalaris* have revealed unusual meiotic behaviour of univalents in the hybrids *P. coerulescens* x *P. minor* and *P. tuberosa* x *P. minor* and a new incompatibility system in *P. coerulescens.* The behaviour of a gene for virescence in *P. coerulescens* and its association with pollen tube growth is being studied.

(iii) *Barley Grass.*—In an effort to produce a pasture type of barley grass without undesirable awn characters, crosses have been made between *Hordeum bulbosum* and awnless types of *H. vulgare.* These hybrids are triploids and will almost certaintly be sterile. The chromosome number of the awnless *H. vulgare* is being doubled so that crosses with *H. bulbosum* will yield fertile progeny.

(iv) Themeda (*Kangaroo Grass*).—A survey of chromosome numbers of *Themeda australis* has revealed three chromosome races 2n = 20, 40, and 60. Further cytotaxonomic and cytogenetic studies will be made on this species.

(*d*) *Basal Sterility in Wheat.*—The inheritance is being studied of a factor or factors for basal sterility which had been discovered in speltoid mutants from three different commercial varieties of wheat. In two of these mutants, St_1 and St_{1a}, the basal flower of each spikelet does not normall develop a grain and may be imperfectly developed or absent. In the third mutant, St_2, the first two flowers of the spikelet are normally sterile. (The studies of morphological and anatomical aspects of this basal sterility have been reported in previous Annual Reports.)

Crosses were made between the different basal sterile mutants, and between the mutants, their parent varieties, and other commercial varieties. Progeny from these crosses have now been grown to the F_2 and F_3 generations, and data on the occurrence of basal sterile spikelets among these plants are being analysed. The expresson of basal sterility is closely linked with that of speltoidy. In the course of this work a proportion of speltoid plants higher than expected have beeen noted to occur.

(*e*) *Developmental Genetics.* — The frequency of genes affecting different physiological activities of flowering plants is being studied in *Arabidopsis thaliana.* This plant is very favourable experimental material for it has a short life cycle (28 days) and can be grown on culture medium. A number of nutritional and morphological mutants have been obtained by X-ray treatment.

A mutant has been obtained which is incapable of synthesizing thiamin. This is the first case of a nutritional mutant to be found in flowering plants. Other mutations include one in which flower initiation and development are temperature sensitive and another in which the growth rate is significantly higher than in untreated plants.

(*f*) *Cytological Polymorphism in Grasshoppers.*—(i) *Cytology of the Genus* Austroicetes.—All but one of the known species of this genus have been investigated. In the *pusilla* group the so-called "inland race" has been shown to be a distinct species, hitherto nnrecognized. Apparent introgressive hybridization between it and *A. pusilla* should be interpreted as phenotypic convergence of two reproductively isolated species in a zone of overlap. This case is of considerable interest since it throws doubt on a number of other instances of introgressive hybridization in animals. The "inland race" shows mnch cytological polymorphism, while *pusilla* appears to be cytologically monomorphic.

(ii) *Comparative Cytology of the Subfamily Morabinae.*—A cytological survey has been made of approximately 40 species of this group to fiud out what species would be suitable for studies of adaptive chromosomal polymorphism in natural populations. Eight species were found to be suitable and future work will be largely devoted to investigating natural populations of *Moraba scurra.* Of the 40 species, 33 have sex mechanism XO iu the male, two are XY, and no less than five have complex sex chromosome mechanisms of the X_1X_2Y type. The latter are of considerable cytogenetic interest.

(iii) *Population Cytogenetics of* Moraba scurra.—This species of the southern tablelands of New South Wales is extremely favorable for fundamental studies on the mechanisms of genetic adaptation to the environment. Structural rearrangements are present in several of its chromosomes. There can be no reasonable doubt that these polymorphic systems are adaptive, but results from young males have not so far yielded unequivocal evidence of natural selection operating to favour the strnctural heterozygotes. Older males and females will be studied later in the season.

The frequencies of the various chromosomal rearrangements varies from one locality to another and some rearrangements may be absent in particular colonies of the species. "Artificial colonies" consisting of mixtures of individuals from several sources have been set up in suitable localities. It is hoped that these will act as "outdoor population cages" aud permit closer selection and adaptation studies.

(*g*) *Radiation Effects on Grasshopper Chromosomes.*—In order to compare tbe radiation sensitivity of different species of a group, 15 species of grasshoppers have been subjected to 50, 100, and 200 r. of 90 kV. X-rays. Radiation sensitivity will be assessed by the amount of chromosome breakage occurring in the different species.

4. General Botany.

(Division of Plant Industry.)

(*a*) *Structural Botany.*—An interesting interpretation of floral morphology in wheat (*Triticum aestivum*), which is not in accord with the generally accepted view but which receives some support from

palaeobotanical evidence, has been derived from studies of histogenesis of flower development. It has been concluded that the wheat flower is morphologically a short branch system. Upon the main axis of the system the palea, lodicules, and carpel are borne as appendages which are homologous with leaves. The ovule or megasporangium is terminal on the main axis whilst the stamens represent the lateral branches of the system. The carpel arises on the main axis, encloses its apex, and so encloses the terminal ovule; the ovule is not borne on the carpel. Examination of the floral development in other grasses and in genera of related families is in progress, in an attempt to obtain a clearer understanding of the morphology and evolutionary origin of the flower in monocotyledons.

Studies of floral development in the base sterile speltoid wheats described last year have been completed (*see* also Section 3 (*d*)). The sterility of the base florets in these types is due to the failure of flower primordia to form or if initiated to differentiate properly all floral parts. The sterility "factor" in its mildest expression results in the suppression of the anterior stamen and a fusion with abnormal development of the lodicules. Suppression of the lateral stamens is the result of the factor's more active operation and complete failure of the flower primordium to differentiate its ultimate expression. Basal sterility seems to have been an important factor in the evolutionary history of the grasses. Other genera are now being examined for the occurrence of basal sterility with an inhibiting mechanism operating in a similar manner to that found in *Triticum*.

(*b*) *Taxonomy and Systematic Botany.*—The number of specimens now incorporated in the herbarium is 31,860. New studies initiated include: (i) a study of variation in *Themeda australis*, which is one of the most widely distributed and important Australian grasses, with a view to providing basic cytotaxonomic data for selecting suitable variants for pasture ultilization; and (ii) the preparation of an index of generic names used for Australian plants.

During a period at Kew as Liaison Officer the systematic botanist checked approximately 3,000 sheets of plants from the Divisional Herbarium against type material, edited and microfilmed some of the Robert Brown manuscripts, and prepared photographs of many type of specimens of Australian plants. Monographs on the genus *Psoralea* and a section of *Helichrysum* were also prepared. Films of these manuscripts have been distributed and copies of the type specimens will be available for distribution later.

5. Microbiology.

(Division of Plant Industry.)

(*a*) *Phytopathology.*—Research programmes in the field of plant disease are concerned with host-pathogen relationships, the effect of environment on disease development, and with various aspects of plant viruses.

(i) *Chemical Basis of Resistance in Potato Tubers to Phytophthora.*—The release of a water-soluble fungicidal factor has been demonstrated in potato tubers interacting with the pathogen in a parabiotic manner. A substance has been extracted from such infected tissue which checks hatching of *Phytophthora sporangia* and germination of zoospores.

(ii) *Antibiotic Studies.*—Streptomycin is taken up by tomato plants through the root system immediately on exposure to treatment. It accumulates by adsorption in plant tissue, and small amounts of "free" streptomycin pass to the outside where it may be found in droplets on the leaf surface. Although an antibacterial, this material has been shown to reduce the severity of attack by blue mould of tobacco and late blight of potato and tomato.

(iii) *Electrodiagnostic Studies.*—Co-operative investigations with Plant Toxicology on the reaction of potato tissue parasitized by *Phytophthora infestans* and by *Pythium ultimum* were completed (*see* section 12).

(iv) *Brown Rot of Stone Fruits.*—The parasite *Sclerotinia fruticola* was found to penetrate readily into young leaves of apricot and other stone fruits. The fungus readily penetrates the fruit epidermis of cherries, plums, and nectarines to reach the highly susceptible fruit parenchyma. Varietal differences in susceptibility were found, and appear to be due to certain properties of the epidermis. Within plantings of Phillips cling peaches in four orchards in the Shepparton district marked differences in the incidence of brown rot were observed. Serious losses occurred on the light soils which were waterlogged after heavy rains a week before harvest. There was comparatively little loss on heavy soil types.

(v) *Blue Mould of Tobacco.*—Resistance of *Nicotiana debneyi* to *Peronospora tabacina* appears to be due to suprasensitivity. Studies have been made on air humidity in relation to intensity of sporulation and it was found that spores are "shot" from the sporophore when the humidity, after having reached 100 per cent., drops below that level.

A reduction in number of tobacco transplants infected with blue mould has been noted in weeded as compared with unweeded fields in the Ovens Valley. A study of environmental conditions suited to seedling production but unsuited to blue mould development has been initiated.

(vi) *Fungicidal Action of Sulphur.*—Studies of adsorption by the leaf surface of gaseous sulphur or sulphur compounds derived from elemental sulphur or from lime sulphur showed that only small quantities of these substances appear to be necessary to produce a fungicidal action on the powdery mildew of subterranean clover. Clover rust, brown rot of stone fruit, and late blight of potato were not affected.

(vii) *Pathogens in Australian Soils.*—The potential of the microbial flora of soils to cause diseases of the potato is being investigated. Virulence is measured by depth of penetration from the cut surfaces of potato tubers, and anatomical studies are made of the parasitized tissue.

(viii) *Hypersensitive Reaction of Host Plant to Virus.*—Where plant viruses can invade their host plants only to a limited extent "local lesions" occur at the point of inoculation. Since the hypersensitivity of *Nicotinia glutinosa* to tobacco mosaic virus is controlled by a single dominant gene, a single substance is probably involved in the reaction. Graft transmissibility and the kinetics of lesion development are being investigated. Strains are employed in anatomical studies to locate the virus in the tissue beyond the lesion.

(ix) *Heritability of Antibody Response to Plant Virus.*—Co-operative work has been commenced, using tobacco mosaic virus and potato virus X, which aims at the understanding of the heritability of the antibody response in rabbits inoculated with these viruses.

(x) *Separation of Virus Complex.*—An attempt is being made to resolve, by physical and biological means, the virus complex present in the orchids *Cattleya* and *Cymbidium* in order to investigate a serological cross-reaction between these viruses and tobacco mosaic virus.

(*b*) Rhizobium *Research.*—The investigation of host and bacterial variation in relation to effective nodulation of important legumes, particularly subterranean clover, has been continued. Studies in host resistance have been extended to include selections made in other species for genetic analysis. The programme now covers studies of nodule anatomy and the cytology of

bacteroids, and also the investigation of the value under Australian conditions of strains of nodule bacteria obtained from the natural habitats overseas of the species concerned.

(i) *Symbiotic Variation in Subterranean Clover.*—Studies on F_2 progenies have shown transgressive inheritance with respect to number and size of nodules produced, this being greatest when the parents are of widely different geographic origin and poor compatibility. Particular attention is being paid to the connexion between nodule abundance and size and the volume of infected tissue within the nodule.

(ii) *Bacterial Strain Variation.*—The type culture collection of nodule bacteria has been enlarged by the addition of the material from both Australian and overseas sources. The economic potential of clover rhizobia from various Mediterranean countries is being investigated.

(iii) *Anatomy of Symbiotic Compatibility.*—Nodules from two selected lines of red clover, the ineffectiveness of which is due to simple recessive factors, were chosen for this study. These lines differ markedly in the cytology and anatomy of their nodules. Bacteroids from effective nodules have their nuclear elements within "perinuclear" regions around which mitochondria-like granules are located; cytochrome oxidase, certain dehydrogenases, and alkaline phosphatase are localized in these granules.

(iv) *Physiology of Infection.*—Production of nodule-inhibiting substances by plant roots is under investigation. The inhibitory effect is produced under a wide range of conditions and the inhibitor appears to be stable with respect to heat.

Bacterial avirulence and the mechanism of infection by rhizobial penetration of the root hair is being investigated.

(v) *Host Resistance.*—Effective nodulation of *Trifolium ambiguum* was obtained by the use of several strains of nodule bacteria obtained from Turkey via the United States of America. However, only a small percentage of plants of the varieties tested have given an effective response and the type of nodulation was somewhat abnormal; the majority of plants gave an intermediate or ineffective response and some remained resistant. Strains of the clover resistant to and compatible with these bacteria are being developed for genetic studies.

Resistant and compatible strains of *Medicago laciniata* are being developed for studies of the nature of resistance in this species and similar preliminary work is being done with *Soya* and *Phaseolus*.

(vi) *Effective Early Nodulation of Subterranean Clover.*—Co-operative investigations with workers at the Regional Pastoral Laboratory, Armidale, on the problem of nodulation of this clover on the granite soils of the New England region are being intensified. No strain of nodule bacteria has been able to establish itself, even under favorable soil moisture conditions, on unfallowed land of this type upon introduction with the seed at the normal rate of inoculation. The virgin soil has been found to have an appreciable bacteriostatic property.

(c) *Soil Microbiology.*—Investigations of the role of soil microorganisms in soil fertility, with particular reference to phosphate and manganese transformations, were continued.

(i) *Phosphate.*—Plant response due to increased phosphate availability sometimes follows addition of organic matter to soil. Studies were undertaken to determine the effect of decomposing organic matter on the solubility of sparingly soluble phosphate. In liquid media the solubility of rock phosphate is increased, but in soil no such increase could be detected on using chemical fractionation procedures.

(ii) *Manganese.*—Manganese salts when applied to soil are oxidized by microorganisms. The mechanism of this oxidation was studied and it is suggested that a new oxidizing enzyme system may be responsible. The nature of the oxidation product is being investigated and its availability to plants will be examined in greater detail.

6. Fruit Investigations.

(Division of Plant Industry.)

(a) *At Hobart.*—(i) *Physiology of Apple Fruits in Relation to Storage Disorders.*—Experiments on the effect of manurial treatments and growth substances on the cell size, physiology, and keeping quality of apples have continued.

The small increase in fruit nitrogen from urea application in spring and the large increase from applications in summer have been confirmed. While there is leaf response to sprays of nitrogen, potash, and phosphorus, there is fruit response to nitrogen only, and there is no modification of the physiology of the additional nitrogen in the fruit by the other two elements applied in this way. Under conditions of nitrogen depletion fewer cells are formed and respiration rate is increased; while the immediate effect of nitrogen depletion may improve the appearance of the fruit, its ultimate effect is to decrease its storage life.

An increase in cell number per fruit relative to fruit size has been achieved by the use of growth substances, but a season of very low susceptibility to storage disorders prevented confirmation of a parallel reduction in disorder incidence. However, an investigation in another direction showed that as regards fruits of the one size from the same tree those which break down first are those with the smaller number of larger cells. These studies of cell responses to manurial and growth substance treatments are helping to clarify the relation between tree nutrition and fruit physiology with the aim of improving keeping quality.

Because of the importance of seed formation on fruit development, studies of the effect of manuring and growth substances on seed numbers have been made. While fruit size is positively correlated with seed number per fruit within a tree, there is a negative correlation of seed number per fruit and mean fruit size between trees. Treatment with growth substances affects seed number per fruit independent of fruit size and without affecting yield.

(ii) *Gas Storage Trials.*—The survey of apple varieties in their reaction to gas storage with low oxygen concentrations is approaching completion and the general suitability of the method demonstrated. The next stage of semi-commercial, pilot-scale trials has commenced. A new type of carbon dioxide scrubber of high absorptive efficiency has been developed and tests with other devices for maintaining gas concentrations in storage rooms have been successful.

(b) *At Applethorpe, Queensland.*—(i) *Bud and Fruit Development in Apples.*—Studies in the fourth year of summer drought showed that Jonathan blossomed lightly but set well, while Granny Smith blossomed well but set poorly. A comparison of watered and drought-parched Jonathans showed lateral growth to continue for at least a month longer in watered trees. By early March, perfect buds were formed on watered trees while those on drought-parched trees were in very early stages of differentiation.

At the balloon stage (one day before opening), blossom buds of healthy Granny Smith averaged one-third more cells than those from trees showing zinc deficiency. This difference was maintained in the fruit set. Fruit set out of season in late summer also showed a reduction in cell numbers.

(ii) *Rootstock Trials.*—Jonathan trees on Malling I. stocks appear more moisture demanding than Northern Spy, and have died in recent dronghts.

Delicious, on Merton stocks, surpass those on Northern Spy at three years. Some 10,000 trees have been produced on Merton rootstocks supplied to the Committee of Direction of Fruit Marketing. Merton 778 and 793 have been used in the main. Merton 789 has been shown susceptible to crown gall.

7. Oil Crops.

(Division of Plant Industry.)

(*a*) *Safflower* (Carthamus tinctorius *L.*).—In cooperation with the various Departments of Agriculture tests were made to determine (i) varietal agronomic performance, (ii) cultural techniques, (iii) comparative yields and monetary returns of safflower, linseed, and wheat.

Varietal and environmental differences in yield, oil content, and oil quality occurred. Close spacing (7 inches) of rows was better than wide (21 or 28 inches); high sowing rate was better than low; in areas of cold wet winters spring sowing was satisfactory; in other areas May sowing was not always preferahle to June sowing. Under low moisture conditions safflower outyielded linseed but the return per acre was less than for wheat. With adequate moisture supply safflower outyielded linseed in terms of oil per acre, and wheat in monetary return.

Safflower is a facultative long-day plant, varieties differing in their photoperiodic requirements. After the formation of the primordia, increased temperatures accelerated flowering. These findings will be utilized in determining the best growing areas and time of sowing, and in accelerated growing of two to three generations in a year as required in a breeding programme.

The mode of inheritance of some agronomically important characters was investigated. Indications are that rust resistance is dominant and monogenically controlled. Progress was made in breeding for yield, oil content, rapid early growth, and spinelessness. Correlation between yield and various morphological yield components were studied.

An unusual type, with an iodine number of 90-100 (normal 147-150) and with fatty acid components of an edible oil, was crossed with normal safflower. Among the segregates of F_2 and F_3 with a low iodine number some with a considerably increased yield were found. Formation of a drying and an edible oil by different varieties of the same species is unique among oil crops. The material was used for genetic studies on inheritance of oil quality and breeding of strains with a different iodine number.

(*b*) *Linseed.*—Studies were continued with a number of linseed varieties and selections developed from a cross of Punjab x Walsh. A number of varieties have proved superior to the commercially grown variety Walsh in yield. Some new selections are significantly better than Walsh in yield and oil content, and variety Punjab in oil quality and rust resistance to Australian races A and B. These selections have now been released for regional trials and their resistance to other rust races is being tested.

Introductions of different species of *Linum* and varieties of linseed have been studied with the view to their utilization in linseed improvement.

(*c*) *Other Oil Crops.*—Introductions of castor bean, rape seed, and *Lallemantia iberica* L., a new crop with a dry oil, have been studied. A world survey of different oil crops has been carried out and Australia's requirements in this field assessed as a basis for planning future research.

8. Tobacco Investigations.

(Division of Plant Industry.)

(*a*) *Genetic and Agronomic Studies.*—(i) *Breeding.*—Breeding for resistance to tobacco mosaic was continued. Seed lines homozygous for the type of resistance derived from *Nicotiana glutinosa* were grown in the principal tobacco-producing areas. Selection on a leaf-quality basis was impracticable owing to heavy blue mould infections. The Ambelema type of resistance has been incorporated into types suitable for areas where temperatures are high during the growing season. Some hybrids combining both types of resistance resemble flue-cured varieties in appearance.

Although *N. glauca* is a symptomless carrier of the yellow dwarf virus, crosses with *N. tabacum* have not provided any *tabacum*-like plants which are symptomless carriers. All are susceptible to the disease.

Species and strains of *Nicotiana* are being tested for resistance to the more serious tobacco diseases, including blue mould and mosaic. Species recorded as resistant to blue mould were crossed to *N. tabacum*. With all the inter-specific crosses obtained, the majority of seeds were not viable or gave rise to plants which died in the early stages of growth.

The inheritance of unpalatability to looper caterpillars in certain tobacco varieties was determined as being due to several genes.

(ii) *Diseases and Disorders.*—Field observations suggest that susceptibility to blue mould may be influenced by environment. At Canberra, blue mould was severe in field plots established to obtain information on occurrence and survival of the disease.

Trials to determine the effect of plant spacing on occurrence of yellow dwarf virus disease were commenced in Canberra.

Frenching investigations in the field were continued at Katherine on an area where plants were severely affected in recent years. Major treatments were spray or furrow irrigations and planting in ridges or flat land. Disease occurrence was low and, with the exception of poorly drained areas, heavy watering did not induce the disease in regrowth of plants which had been cut back. In greenhouse experiments at Canberra frenching developed more quickly when tobacco followed other crops. It was shown that a frenching factor can be concentrated by centrifuging of soil filtrates and by chemical flocculation. It was also found that soil treatment with a vanadium compound controlled and sometimes prevented frenching.

Leaf curl, a virus disease of importance in some overseas tobacco areas, which was found for the first time in Australia at the Ord River, Western Australia, in 1953, has now been observed at Katherine, Northern Territory.

(iii) *Spectral Properties of Tobacco Leaves.*—In studies of light distribution within crops shading was shown to be a serious problem. Intensities recorded were far below the minimum for adequate photosynthesis.

Measurements show that leaves grown at the low light have greater transmittance than, but approximately the same reflectance capacity as, leaves grown at high light intensities. Tobacco leaves absorb and filter white light, and so contribute to the poor radiant energy supply in the dense tobacco stands.

(iv) *Self- and Total Shading of Tobacco Plants.*—Studies were carried out of self- and total shading (i.e., self-shading plus shading by adjacent plants) as affected by the different positions of the sun throughout the day during the growing period. Comparison of shading in east-west and north-south rows indicate a considerable difference in shading pattern throughout the day between the two aspects, and effects were more pronounced in plants provided with high nitrogen. Further work is required to establish the degree of importance of shading patterns produced.

(*b*) *Tobacco Chemistry.—Development of Amenenic Leaf in Tobacco.*—It has been shown that this leaf has low hexose carbohydrate food reserves and high nitrogen content relative to sugar content. These characters can change rapidly with environmental conditions. Adequate light and control of nutrient nitrogen are necessary for normal leaf development.

(*c*) *Tobacco Quality.*—Studies on the effect of nutrient status on leaf quality have been continued at the Waite Agricultural Research Institute, Adelaide, South Australia.

(*d*) *Tobacco Physiology.*—Field studies in Queensland have shown that a wide range of mineral oils will control sucker growth if applied to the cut surface of the stem at "topping".

9. General Chemistry.

(*a*) *Chemical Techniques.*—(i) *Determination of Nitrates in Soils.*—A modification of the phenoldisulphonic acid method for the determination of nitrates in soils has been developed. The soil nitrate extract is made alkaline and evaporated to dryness, and hot phenoldisulphonic acid is added. After neutralization with sodium hydroxide the colour intensity is measured the following day. Small sample weights of soil and short extraction time eliminate cation interference.

(ii) *Water-soluble Sulphate Determination in Soils.*—The soil is extracted with sodium chloride solution in order to release sulphate from colloids. Sulphate is then turbidimetrically determined after the clear extract was treated with "seeded barium chloride".

(*b*) *Plant Growth Disturbances.*—(i) *Frenching in Tobacco.*—Lead toxicity has been suspected as a cause of frenching in tobacco. Pot culture experiments on pure acid-washed sand with basic lead carbonate added to nutrient solution were carried ont. It was possible to induce reticular chlorosis in tobacco leaves similar to that encountered in the early stages of frenching in tobacco grown on soil at a level of 50 p.p.m. of lead. Further investigations are in progress.

(*c*) *Nutrient Availability.*—(i) *Sulphur.*—It is assumed that only sulphate sulphur is available to the plants. Investigations have shown that most of the soil sulphur is associated with the soil organic matter and mostly only a very small fraction of total sulphur is present in a form of sulphate. One preliminary experiment of soil incubation on a natural bacterial flora has shown no changes in sulphnr status but a gradual increase in the nitrate content in different soils while incubated. This may indicate why soils with a high organic sulphur content may nevertheless produce sulphur-deficient plants.

An experiment to study obstacles governing the oxidation of sulphur in those soils has been commenced. Eleven different soils will be incubated with and without added sulphur-oxidizing bacteria.

A further experiment is planned to investigate whether sulphates are the only sulphur source for the plants.

(*d*) *Plant Nutrients.*—(i) *Sulphur and Phosphorus.*—Oats were grown on eleven different soils with applied sulphur, phosphorus, and both sulphur and phosphorus in pots. Response was obtained in almost all soils. Chemical analyses of harvested plants and soils are in progress.

(ii) *Trace Elements.*—Oats grown on a soil of granitic origin have shown severe deficiency symptoms other than those of sulphur and phosphorus. Some improvement has followed applications of nitrogen plus sulphur or phosphorus, but none with sulphur and phosphorus. The possibility of trace element deficiencies is being investigated.

(iii) Pinus radiata *Trial.*—Uptake of molybdenum, boron, copper, magnesium, nickel, and zinc by pines following soil additions will be investigated in co-operation with the Forestry and Timber Bureau.

(*e*) *Cobalt Uptake by* Phalaris.—Investigations to study differences in cobalt content and uptake between ecotypes of *Phalaris* are being continued.

10. Plant Nutrition.

(Division of Plant Industry.)

(*a*) *Defining Nutrient Requirements for Soils.*—Research with the major elements, particularly phosphorus, sulphur, and nitrogen, and with the trace elements, has been responsible for considerable changes in fertilizer practice over recent years. Apart from the influence on the primary industries, this has considerably altered the nature of the research now being done in many branches of agriculture.

Further studies on the soils of the Heytesbury region of Victoria show that the main effect of lime on that soil is due to the improvement in the nodulation of the clover. The greatest response to the lime occurs in the year of sowing. In that year, a high proportion of the clover plants do not form nodules if the seed is sown without lime. The nodulation improves with time, and the response to lime becomes less in second and subsequent years.

Rhizobium was isolated from plants that had nodulated in the first year without lime. This *Rhizobium* was then used to inoculate clover seed to compare it with the cultures of *Rhizobium* being used normally for inoculation. There was no evidence that the *Rhizobium* from these plants that had nodulated without lime was in any way superior. The best results were obtained only when lime was used with the inoculated seed.

There was a high residual effect of copper on the soils at Heytesbury. A dressing of 7 lb. of copper sulphate per acre applied at sowing gave as much as an eightfold increase in the yield of clover in the second year. Retreatment with 7 lb. per acre in the second year had no further effect.

(*b*) *Plant Nutrition Survey.*—A preliminary survey of deficiency problems was made in co-operation with the New South Wales Department of Agriculture. The survey extended from the Queensland to the Victorian borders and as far westward as Inverell, Gunnedah, Dubbo, and Wagga. Eighty-nine trials were inspected, some of which were established by officers of the Department of Agriculture, but most were established by farmers.

The survey has provided a much clearer picture of the distribution of deficiencies in New South Wales pastures. Of the trace elements, responses to molybdennm were obtained in a number of places, bnt there were no significant deficiencies of copper, zinc, manganese, or boron. Also there were no deficiencies of magnesium or potash.

In many places there were impressive responses to the heavier dressings of superphosphate used in the trials, in comparison with the responses obtained when normal levels were used. An outstanding result of the trials is the indication that in many areas much better results would be obtained if heavier dressings of superphosphate were applied in the early years after sowing.

The trials showed the widespread occurrence of defective nodulation in newly sown clover on acid soils, and the importance of lime on these soils to induce nodulation.

(*c*) *Characterizing Deficient Soils.*—Subterranean clover was grown on 32 virgin soils in pot cultures, and the yield responses to phosphorus, sulphur, and

molybdenum were determined, to allow examination of the influence of climate, the geological origin of the parent material, and various soil characters on the occurrence and intensity of deficiencies.

On only two soils was there no significant response to phosphorus, and even on these soils the effect was positive and may have been real. This result is of special importance in indicating that if there are any virgin soils where phosphorus is not deficient at all and where responses to sulphur alone may occur, they must be rare. It is clear that for most soils a fertilizer containing both phosphorus and sulphur is needed. In these experiments, three-quarters of the soils required both phosphorus and sulphur.

A third of the soils were deficient in phosphorus, sulphur, and molybdenum. There was no correlation between response and most of the soil factors examined. The significant correlations were between soil type and phosphorus responses, and between soil pH and sulphur and molybdenum response. Responses to phosphorus were less on the black earths than on the red and yellow podzolics. The intensity of sulphur deficiency was greater in the neutral to alkaline soils than in the acid soils. This contrasts with the relationship between soil pH and molybdenum response, the response to molybdenum being greater in acid soils. These correlations are not sufficiently high to make soil reaction a useful indication of the deficiency in any particular instance.

(*d*) *Supply and Availability of Elements.*—It has recently been shown that phosphates increase the uptake of molybdenum. However, in the pot culture experiment with a wide range of deficient soils, in no case did phosphate correct molybdenum deficiency by increasing the uptake of molybdenum. In all cases molybdenum was most deficient where phosphate had been applied.

Studies with lime have provided further evidence of the special importance of lime on very acid soils for the survival of *Rhizobium* and the nodulation of legumes.

(*e*) *Factors Affecting the Response.*—The pot culture experiment with a wide range of deficient soils showed the special importance of the interaction between elements in determining the distribution of deficiencies. There was no response to molybdenum at all on any of the soils where no phosphorus or sulphur had been added. Where phosphorus and sulphur had been added deficiencies of molybdenum were found in a third of the soils. The number of soils deficient in sulphur was increased nearly threefold by the application of phosphorus and molybdenum.

(*f*) *The Role of Elements in Plants.*—Experiments with molybdenum-deficient plants have shown that application of molybdenum increases the concentration of amides and amino acids within two hours after application. The concentration of amides and amino acids is low in molybdenum-deficient plants. By contrast with molybdenum, deficiencies of manganese, copper, zinc, and iron increase the concentration of amino nitrogen.

The possible role of zinc in plants in carbonic anhydrase is also being examined. Animal carbonic anhydrase contains zinc. This zinc is firmly bound in a thermostable tripeptide co-factor. All efforts to establish whether plant carbonic anhydrase contains zinc have failed. Plants grown in nutrient solution have been given radioactive zinc, and the carbonic anhydrase has been extracted from the green leaves. The enzyme has proved to be particularly labile. The best results have been obtained by fractionation with calcium phosphate gel at carefully controlled pH and ionic concentrations. The methods so far developed will be used to further purify the enzyme.

11. Mineral Nutrition of Plants.

(Division of Biochemistry and General Nutrition.)

The solution-culture experiments mentioned in the previous Report have been continued with three main objects in view, viz.: (*a*) to improve techniques of raising plants to maturity under these conditions, (*b*) to re-examine the visual symptoms of nutrient deficiencies, and (*c*) to examine the uptake of zinc and copper and their distribution in the plant at intervals during the growing period. *Trifolium subterraneum* var. Bacchus Marsh was used as a test plant in these experiments.

(*a*) Adjustments of the concentration and proportions of salts in the culture solutions, appropriate supplementary additions from time to time, and the employment of conductivity measurements to provide against inadequate or excessive concentrations of nutrient salts have, by considerably enhancing the rate of growth and the seed production, more nearly achieved optimal conditions for the development of this plant.

(*b*) Experience of inducing deficiency symptoms has been considerably extended; and the lesions of Ca, K, Mg, Fe, B, Mn, Cu, and Zn deficiencies have been studied.

(*c*) Changes in the distribution of zinc and copper were investigated in seedlings under different nutritional conditions during the first 40 days subsequent to germination. The onset of deficiency symptoms of plants grown under a wide range of deficiency conditions was studied. Translocation trends were determined by chemical analyses of plant tissues collected by frequent harvests throughout the whole growing period.

In this series of experiments Zn^{65} of high specific activity has been employed to determine more precisely the location of zinc within the plant tissues.

The results illuminate the physiology of zinc utilization by the plant, and provide a key to the recognition of different states of deficiency.

12. Plant Toxicology.

(Division of Plant Industry.)

(*a*) *Herbicide Tests.*—Further compounds prepared by the New South Wales University of Technology have been tested. It has been found that less than 1 per cent. of the 2-methyl carbon in radioactive "Methoxone" is liberated as carbon dioxide, so that this radioactive compound is of use in physiological studies.

(*b*) *Mistletoe Investigations.*—Collaborative work with the Forestry and Timber Bureau has shown that, under local conditions, a second injection of 2,4-D will destroy most surviving mistletoes and does not necessarily injure the host trees. It may be unnecessary to aim at 100 per cent. kill with one treatment, because within two or three years reinfection occurs in some localities. Nevertheless, efforts are being made to improve the efficiency of trunk injections, as comparatively poor results are reported in Queensland and South Australia, and trials with additional compounds are in progress.

(*c*) 2,4-D *Bioassay.*—A suitable method has been established for the bioassay of minute amounts of 2,4-D.

(*d*) *Impedance Studies.*—The impedance equipment for measuring injury has been considerably improved. In collaboration with the Microbiology Section, an investigation on the injury caused to potato tubers by some fungal diseases has been completed. The investigation shows that where the tuber is susceptible to a strain of the Irish blight organism, the tuber initially tolerates the pathogen. On the other hand, when the tuber is resistant it does not tolerate the pathogen, is rapidly injured, and its cells are injured in advance of the pathogen. The last phenomenon is associated with the resistance mechanism of the tuber.

(*e*) *Translocation.*—Waterlogging impairs the metabolic translocation of poisons in the roots of *Hypochaeris radicata.*

13. Plant Physiology.

(Division of Plant Industry.)

Investigations have been carried out in three main fields in addition to those of a miscellaneous nature.

(*a*) *Hormone Physiology.* — (i) *Frenching of Tobacco.*—The symptoms of frenching suggest a disturbance in the hormone-controlled growth reactions of the plant; but since a wide variety of apparently unrelated agencies can produce or simulate the condition, it is suggested that each agency acts through a central hormone-controlled mechanism. This hypothesis is under test by an examination of the status of normal and frenched plants with respect to plant growth hormones and inhibitors.

An assay procedure has been established capable of extracting and concentrating such substances (which commonly occur in plants at concentrations less than 1 p.p.m.), separating them by chromatography on paper, and assessing activity by the *Avena* coleoptile section elongation test.

In preliminary analyses, extracts of stems and leaves of normal young tobacco plants were shown to contain the main promoter, indolylacetic acid (IAA), and a previously encountered, but not yet indentified, acid growth promoter and an inhibitor. Extracts of similar frenched plants contained no detectable IAA, but considerably more of a new non-acidic inhibitor than observed in normal plants. This dissimilarity of pattern thus supports the initial hypothesis.

(ii) *Hormone Transport.*—Not only content but also movement within the plant of hormones or auxins is significant in their controlling action on plant development. Normally auxin movement is polar and basipetal. Recent work has instanced circumstances under which polarity is lost and acropetal movement also occurs.

Work, still in the preliminary stages, has been begun to test and extend such ideas with special reference to consequential effects on flower initiation.

(*b*) *Plant Development.*—(i) *Skeleton Weed.*—Little has hitherto been known about the conditions required for flowering by skeleton weed (*Chondrilla juncea*). It has been shown that skeleton weed cannot flower unless the days are sufficiently long. Plants have been maintained strictly vegetative for one year by keeping them under short-day (8 hour) conditions. They could be made to flower by ten exposures to a long day (20 hours). Such considerations are significant to distribution and dispersal studies.

(ii) Anagallis arvensis.—Further work has been carried out on this laboratory test plant which serves as a convenient model for others of agronomic importance. Conditions have been established under which plants may, at will, be held just "poised" in continued vegetation or tipped towards reproduction. The minimum amount of leaf area required to perceive a light stimulus has been established as 10 mm^2. Area *per se* is the determinant and not age (except that cotyledons are ineffective). Two strains have been isolated with differing requirements of photoperiod and cold experience. These requirements have been quantitatively established.

(iii) Phalaris tuberosa.—In continuation of this project, monthly plantings of *P. tuberosa* in the field have been made throughout the year. From records of dates of heading, and times of flower initiation as determined by serial dissections, obtained both from this material and some previously grown in the glasshouse, it is concluded that formation of flowers in *Phalaris* is hastened by long days, with indications as well that it is inhibited by high temperatures. It is hoped to give precision to these findings by growth-room studies.

(*c*) *Seed Physiology.*—(i) *Dormancy in Subterranean Clover.*—Previous work on the favorable actions of treatment with cold and removal of testae has been confirmed and extended. Two new, and more effective, methods of breaking dormancy have been established and investigated, viz., treatment with carbon dioxide, and certain activated carbons. The lowest calibrated concentration of carbon dioxide shown to be effective is 2 per cent.—the minimum is probably lower. An examination of the mechanisms of these effects is being actively pursued. Dormancy of seed is not a problem in establishment of subterranean clover pastures; but it is a matter of some significance in evolutionary studies and breeding programmes. The method has already been used to establish valuable crosses unresponsive to conventional treatment.

(ii) *Non-viable Embryos.*—Certain *Hordeum* crosses (*H. vulgare* var. Marett Awnless by *H. bulbosum* 13798-2) produce non-viable seed. Embyos have been explanted, cultured by methods referred to in an earlier Report, and grown into viable plants.

(iii) *Germination Inhibitor.*—Extracts of seed coats of *Echium plantagineum* have not yielded substances which are inhibitory to the germination of *Echium* seed (as was earlier thought possible), and which could have been the cause of dormancy. However, such extracts markedly retard the development of roots of *Echium* embryos. Extracts of *Echium* seed coats do, however, act inhibitorily on the germination of other seeds, e.g., cress, and work to characterize the responsible substance(s) is in progress.

(*d*) *General.*—(i) *Nitrogen Metabolism.*—The most interesting finding, using embryos of *Medicago orbicularis,* is the different behaviour of some amides and the corresponding amino acids. In the case of amides, glutamine is a superior source of nitrogen to asparagine, whereas glutamic acid is inferior to aspartic acid.

From a comparative study on nine families (monocotyledons and dicotyledons) it is concluded that glutamine is superior to asparagine as a nitrogen source for embryo growth. It is interesting that asparagine is actually inhibitory only in representatives of Cruciferae and in the one species investigated of the closely related Resedaceae.

(ii) *Sterility Study.*—The culture of inflorescence primordia of the basal sterile speltoid wheat, St. 2, has proved difficult. After investigating a wide range of media and conditions, only limited growth is yet obtainable. The requisite sucrose concentration in the medium has been established to be greater than that usually held satisfactory for tissue cultures.

(iii) *Soil Fertility.*—An investigation of the effects on crop growth of adding organic matter to the soil was conducted at Griffith, New South Wales, over a period of years. The dominant finding of the field experiments was that crop growth was stimulated by an increased intake of phosphorus from the soil. This finding is relevant to the important general problem of the availability of nutrient elements as influenced by the presence or absence of organic matter in the soil.

The implication of the present experiments is that relatively unavailable phosphorus can be made available by ploughing in crop residues such as straw or stubble. Pot experiments and laboratory studies are now in progress to find the conditions under which this can take place. Results to date show that in some circumstances phosphorus can be made less and not more available to the crop. It is hoped that the work will throw some light on a subject concerning which there is much conflicting evidence.

(iv) *Phosphorus Deficiency in Citrus.*—From a study of leaf composition in citrus, varying degrees of phosphorus deficiency were found in an experimental citrus grove at Griffith, New South Wales. This finding suggested the possibility that, as in parts of California, phosphorus deficiency may be responsible for the poor quality of some oranges produced on the Murrumbidgee Irrigation Area. This lead has been followed at Griffith, and a farm survey has shown beyond reasonable doubt that phosphorus deficiency and fruit quality are strongly associated.

14. Plant Ecology.

(Division of Plant Industry.)

(*a*) *Vegetation Survey of Southern Tablelands.*—Further collections have been made and the compilation of detailed notes of some areas has been completed.

(*b*) *Studies on Native Grasslands.* (i) *Invasion of Native Pastures by* Bothriochloa ambigua.—Climatic conditions have not been conducive to spread of this species. Studies in root development of *B. ambigua* and *Danthonia* spp. suggest that under conditions of adequate moisture and high temperature, growth rate is greater in the former species. The vigour and vitality of seed of *B. ambigua* is greatly reduced by twelve months' storage.

(ii) *Autecological Studies on Native Species, Trangie, New South Wales.*—The economy of the Trangie district is based largely on grazing introduced forage animals on native annual and perennial species. This project is designed to find the interrelations between the major native plant species and the microenvironmental factors, excluding nutrition, by using plant growth as the major measuring index. Preliminary work has indicated that within this environment growth rates as well as the seasonal variation of species are dependent on soil moisture, temperature, and solar radiation. The interrelations between these three factors are to be further studied using potted native species grown under partially controlled conditions.

(*c*) *Subalpine Grassland Studies.*—The reasons why trees do not grow on subalpine grasslands in the Monaro region were studied further during the year; particular attention was given to the recording of air temperature profiles in contiguous grassland and woodland. Studies were initiated of the effect of the tree canopy in modifying the temperature microclimate. A further series of young eucalypt trees of varying cold tolerance were planted in a transect across the grassland-woodland boundary and their reaction to the different environments was studied.

The relation of the tree line to contour is being investigated from air photographs.

(*d*) *Ecological Studies on Weeds.*—(i) *Competition between Pasture Plants and Perennial Weeds.*—*St. John's Wort*: The factors in the successful control of St. John's wort by subterranean clover under field conditions at Tumbarumba, New South Wales, have been studied in specially designed competition boxes in the glass-house. It is expected that when the second series of experiments are completed this year this work will be concluded.

Skeleton Weed: Field experiments at Cowra, New South Wales, indicated that under the dry conditions experienced last year pasture plants did not effectively compete with skeleton weed, although under the more favorable conditions of 1953 they had markedly reduced the skeleton weed population.

Hoary Cress: The effect of Wimmera ryegrass on the control of hoary cress by phenoxyacetate acid compounds in being investigated at Murtoa, Victoria. Wimmera ryegrass and other grasses including cereals appear to aid the control of the weed by chemicals. More detailed studies of the effect of the grasses is planned under controlled glass-house conditions next year.

(ii) *Skeleton Weed.*—It is unlikely that chemical weed control techniques can be used to eliminate skeleton weed, and current work is designed to determine field conditions which reduce skeleton weed numbers in pastures and to develop techniques to overcome the reduction of crop yields. This work will be continued in the coming season. The assessment of the competition offered to skeleton weed by various pasture species has been continued. The reduction achieved by lucerne stands appears to be due to competition for water; further confirmation of this result will be obtained in the coming season when the current trials will be terminated.

Competition between skeleton weed and a crop of wheat for nitrogen is very severe when soil nitrogen is low. In one trial, where fertility was high following three years of pasture, the effect of the weed on the yield was not detectable.

A further means of reducing the competitive effects of skeleton weed applicable to early sown oat crops is early spraying with herbicides of the 2,4-D type, and this technique is being used to study competition between weed and crop for nitrogen.

Studies of the assimilation and storage of carbohydrate reserves by skeleton weed were started during the year with a view to reassessing the possibilities of control by management and cultural methods.

(iii) Nasella Trichotomo (*Yass River Tussock*).—This important weed of pastures is spreading on the Central and Southern Tablelands of New South Wales and work in progress offers promise of control. The weed can be controlled on arable lands by conventional cultivation and establishment of vigorous pastnres, although costs are increased by its presence. Stands of the weed on stony shallow soils in rough country are the major problem and here chemical control with sodium trichloracetate has been successful. Unfortunately, the treatment is successful only if rain falls within a few weeks after treatment. In one experiment on steep rocky ground subterranean clover stands were established following treatment and no seedlings have established after three years. Work on conditions favouring establishment of the weed continues. At another site further trials have been laid down with a view to reducing costs and devising formulations independent of following rains. In all herbicide trial, as a routine, subterranean clover is broadcast with the appropriate fertilizers and in all cases a pasture has been established.

(iv) *Competition Studies.*—Further experiments on interplant competition are in progress as a preliminary to a study of competition between pasture species and weeds to be carried out in pots. Effects of light intensity and nitrogen supply on leaf area growth under different levels of competition from other plants are of major interest. Leafiness has been confirmed as an important factor in yield increment of a plant or plant community.

(*e*) *Grazing Management Experiment—Mitchell Laboratory, Trangie.*—This project, which is being conducted in co-operation with the New South Wales Department of Agriculture, is designed to obtain information on management problems of the semi-arid *Chloris* pastures using various percentages of grazed lucerne as a supplement.

A group of pen-fed sheep are to be incorporated as an essential control and all the varying grazing intensities on natural pastures or with lucerne supplements are to be considered as treatments.

The food-value basis of the pastures is to be assessed on protein values. Information concerning the economics of growing lucerne, as well as the most economic percentage of lucerne to use in this area, will be obtained.

Wool production due to (i) the environment, (ii) environment plus natural pastures, (iii) environment plus natural pastures plus a lucerne supplement, will be determined. Since both grazing intensities and nutritional levels will fluctuate, wool production will be measured at short-term intervals, rather than by using a single estimate in the form of a twelve-monthly fleece weight.

(*f*) *Eucalypt Studies.*—(i) *Nutrient Status of the Soils of the* E. polyanthemos-E. melliodora *and the* E. melliodora-E. blakelyi *Associations.*—Soils from five of each of the associations have been shown to be deficient in nitrogen, phosphorus, and sulphur. Yield was depressed by potassium and no response obtained with minor elements. Soils of the *E. polyanthemos-E. melliodora* association contained significantly higher levels of available phosphorus.

This type of work has been extended to the *E. rossii* and *E. melliodora-E. blakelyi* Associations.

(ii) *Effect of Phosphorus on Interspecific and Intraspecific Competition in* E. polyanthemos *and* E. melliodora.—An experiment to determine the role of level of soil phosphorus in the distribution of these species has been commenced. Trees have recently been transplanted to field plots in pure stands and mixed communities at a spacing of two feet between trees. Two levels of phosphorus, nil and 4 cwt./acre $CaHPO_4$, have been applied.

(iii) *Nutrition of* E. polyanthemos *and* E. melliodora.—The response to calcium, nitrogen, phosphorus, potassium, sulphur, and lime was investigated in sand culture. Lime depressed growth in both species. *E. polyanthemos* responded to all elements but no response was obtained with *E. melliodora* in the case of sulphur and potassium.

Both species responded more to phosphorus than to nitrogen, and response to phosphorus was greater in *E. polyanthemos.*

A similar trial using *E. fastigata* and *E. bicostata* has been commenced. The depressing effect of lime has been established and responses to phosphorus, nitrogen, sulphur, and potassium appear likely.

15. Plant Biochemistry.

(Division of Plant Industry.)

(*a*) *Morphogenesis.*—The work has centred around the biochemical processes concerned in the differentiation of cells in regenerating plant organs. The problems considered are basic to the normal growth and development of higher plants and are pertinent to such practical problems as vegetative propagation (e.g. stem and root cuttings, control of regenerating weeds), perenniality, and development of abnormal tissue.

Using aseptic tissue culture techniques, fragments of many kinds of regenerating tissue have been exposed to a defined chemical and physical microenvironment. Addition of very low concentrations of structural analogues of the purines and pyrimidines (e.g. substituted benzimidazoles, benztriazoles, thiouracils, and barbiturates) proved effective in inhibiting the production of adventitious meristems.

In examining the question as to why some species sucker while closely related species do not, a study has been made of the growth factor requirements of isolated roots of *Lycopersicon, Medicago,* and *Trifolium* species. Those vitamins and amino acids normally provided by the leaves are being determined.

Preliminary experiments on the chemical pathways in nucleotide synthesis in plants have been carried out. Present indications are that substances similar to those known to be intermediates in micro-organisms and in animals may be involved. Nucleotides and the related nucleic acids are rapidly synthesized in regions of cell division activity.

(*b*) *Buffering Capacities of Some Excised Plant Tissues.*—Sections of tissues commonly used in bioassays and growth tests were potentiometrically titrated with dilute acids and bases. This reveals the extent to which test tissues themselves may buffer the external medium and thus influence the rate of uptake of dissociable molecules (e.g., auxins, nutrient ions). By measuring the buffering capacities of root tips as a function of pH in the presence and absence of nutrient ions, one may learn something of the nature of the sites at which these ions are bound on the root surface, prior to their uptake.

(*c*) *The Biochemical Role of Zinc.*—In animals, zinc is associated with the enzyme, carbonic anhydrase. In plants its biochemical role is not known. Experiments were undertaken to see if zinc is also part of plant carbonic anhydrase. Plants grown in water culture were fed a radioactive isotope of zinc, as a tracer. If the zinc is incorporated into carbonic anhydrase, the radioactivity should be inseparable from the enzymatic activity during purification of the enzyme. Methods of purification are at present under study.

(*d*) *Enzyme Studies.*—Studies on dehydrogenase enzymes and cytochromes of yeast and higher plants have been continued in the Department of Biochemistry, University of Melbourne.

The properties of the enzyme "yeast lactic acid dehydrogenase", have been further examined.

Microchemical analyses showed that the total iron content of the enzyme was accounted for in haem, one of the two prosthetic groups previously described. The high phosphorus content indicated the presence of this element other than as a component of the second prosthetic group, riboflavine phosphate, and is accounted for by the identification of polynucleotide as a further component of the crystalline enzyme. The chemical composition and enzymic function of this nucleotide are being investigated.

Electrophoresis, ultracentrifugation, resin chromatography, and salt precipitation have been used in attempts to isolate separate protein components conjugated with the various prosthetic groups. Free flavine can be dissociated under a variety of conditions, resulting in a loss of enzymic activity, but in no case has a separate flavoprotein, active or inactive, been obtained. Free nucleotide has also been dissociated, but the effect of its removal on enzymic activity is still to be fully determined.

The sedimentation behaviour of the enzyme in the ultracentrifuge and its amino acid composition have been studied in the collaboration of the Wool Textile Research Laboratories, Biochemistry Unit.

The complex nature of this enzyme suggests that it may catalyse the esterification of inorganic phosphate, coupled with the oxidation of lactate.

16. Phytochemical Survey.

(Division of Plant Industry.)

The co-operation of the Division has continued in the provision of plant samples and botanical advice. About 130 bulk samples for analysis were collected by officers of the Division stationed at Brisbane and by officers of the Forestry Departments of Queensland and New South Wales.

Besides co-operating with Australian laboratories, samples have been forwarded to overseas institutions for specialized examination. Numerous samples have been sent to the National Institute of Health, Bethesda, United States of America, which is screening plants for tumour-damaging principles. About four Australian plants of rain-forest origin have given positive tests worthy of mention. Investigation of the toxic principle (reputed to cause blindness) in wannakai or finger

cherry (*Rhodomyrtus macrocarpa*) being carried out at the Chemistry Department, University of Leeds, England, has reached a promising stage.

A search for reserpine in indigenous members of the family Apocynaceae resulted in the identification of this therapeutic alkaloid by the Division of Industrial Chemistry, C.S.I.R.O., Melbourne, in root bark of *Alstonia constricta*. A survey and collection of this and related species were made by officers of the Division in Queensland.

Several specimens of reputed native medicines were collected for analysis in Australia through the courtesy of officers of the Administration of Papua-New Guinea.

Collection and chemical analysis of selected plants poisonous to live-stock have been arranged, mainly in conjunction with the Queensland Department of Agriculture and Stock.

A paper dealing with the chemistry and taxonomy of the Australian flora, which will collate chemical results on specimens collected since the survey began in 1945, is in preparation.

17. Organic Chemistry.

(Division of Plant Industry.)

(*a*) *Potato Pathogen Investigations.*—(i) Phytophthora infestans.—Work is being carried out to determine whether the resistance of certain varieties of potato to late blight pathogen (*Phytophthora infestans*) is caused by the presence of or formation of a toxin in the host tissue. Some progress has been made with the separation of a factor showing toxic effects on *Phytophthora* zoospores.

(ii) Pythium ultimum.—The rapidity with which the soft rot parasite (*Pythium ultimum*) of potato causes destruction of the host tissue has led to an attempt to find a toxin liberated by the pathogen. An assay technique using the impedance measurements described by the Plant Toxicology Section (Annual Report 1953-54, III.-15) has been developed, and the fractionation of extracts showing toxicity is in progress.

(*b*) Lolium *spp. Root Exudate.*—The appearance of areas of intense fluorescence around the roots of Italian ryegrass (*Lolium multiflorum*) when germinated on moist filter paper has been used for some years to distinguish it from perennial ryegrass (*Lolium perenne*) which exhibits no fluorescence. An investigation is being made of the chemistry of this material in order to assist work on the genetical factors controlling the formation of the exudate.

(*c*) Duboisia myoporoides.—A sample of *Duboisia myoporoides* from Queensland has been found to contain a previously unreported volatile alkaloid which is being investigated.

(*d*) *Linamarin and Lotaustralin.*—The synthesis of linamarin and lotaustralin, the two cyanogenetic glycosides reported to occur in New Zealand white clover (*Trifolium repens*), is in progress. These glycosides will assist with the genetic studies on this species.

18. Pasture Investigations, Canberra, Australian Capital Territory.

(Division of Plant Industry.)

(*a*) *Pasture Utilization.*—Except in most favoured climatic areas the rate of growth of pastures (and crops for stock feeding) fluctuates widely throughout the year, and from year to year. The requirements of livestock also vary throughout the season, depending on the type of production practised, but these seasonal variations of feed demand are of much less intensity than those of feed supply, and are relatively stable from year to year. Production of animal products is limited by the length of the periods and intensity therein, of feed deficit, whether real because of an absence of plant material, or artificial because of lowered ingestion or digestion or both in the presence of adequate material. These periods of feed deficit by restricting overall carrying capacity impose a low degree of utilization in the often relatively short period when the pasture is excessive in quantity and adequate in quality, and result in an enormous annual wastage of feed otherwise potentially capable of conversion into animal products.

Extremely few recommended methods for increasing pasture production have been critically examined in relation to their worth for animal production. Examination of a heavily top-dressed phalaris-subterranean clover pasture at Canberra (in comparison with pastures of lesser productivity) has indicated that the increased animal yields obtained cannot be ascribed to the greater spring growth but to some decrease in the length and severity of the period of deficit, plus an increase in the quality of the ingested material. High-producing pastures make their greatest yield contribution when least needed, and the increased carry-over of dry material into the subsequent period of deficit is of little or no benefit to the animal. The greater fluctuations in seasonal growth by improved pastures therefore require complementary methods of management if their greater potential is to be fully utilized by the animal.

(*b*) *Pasture Management.*—(i) *Conservation.*—The practice of conservation of feed in excess of that which can be utilized by the animal whilst the pasture is at a nutritious stage of growth, to provide feed for later periods of deficiency, alters the pressure of grazing during the periods both of collection and feed-back of the reserves. Long-term studies of the behaviour of the pasture under various systems of conservation and increasing degree of utilization and of their relation to animal production are being continued. Previously reported results of increased wool yields and doubled liveweight gains from the most highly utilized pasture have been repeated. Examination is also being made of the separate effects within the process of high utilization, such as degree of defoliation, density of summer vegetative cover, and return of animal droppings, on the recovery of the pasture in subsequent seasons.

(ii) *Crop Interposition.*—A field experiment has been commenced to measure the effect on the pasture and resultant animal production of periodically reducing the nitrogen status by cash cropping, and thereby re-stimulating the nitrogen-fixing potentiality of the clover constituent. A further experiment is proposed to study the crop-pasture relationships in grazing systems aimed at providing better standards of nutrition for breeding ewes.

(iii) *Types of Live-stock.*—A study of the effects on pasture of sheep and beef cattle, separately and together, will be commenced in the current year.

(*c*) *Pasture Mixture Trials.*—The addition of *Agropyron obtusiusculum, Bromus coloratus, B. inermis, Dactylis glomerata,* and *Festuca arundinacea* to a *Phalaris tuberosa—Trifolium subterraneum* pasture mixture gave no significant increase in total annual production of herbage, but there were seasonal changes in growth rhythm. The inclusion of another perennial grass when sowing phalaris-subterranean clover pastures may have application as a means of combating "phalaris staggers".

(*d*) *Spacing Trials*: Phalaris tuberosa.—Greater yields of phalaris per acre have been obtained from widely spaced plants than from closely spaced plants. In addition, wider spacing permits better growth of subterranean clover, which futher increases yield per acre.

(*e*) *Medic Studies.*—(i) *Regeneration.*—Cultivation, dense cover of herbage residues, and irrigation all increased re-establishment of medic. Subterranean clover is less dependent on these variables. Imbibition

trials have shown that medic seed reqnires to take up twice its own weight of water for germination whereas subterranean clover required only its own weight.

(ii) *Nutrition.*—Experimental plots in the Wagga and Temora areas have shown a marked response to molybdenum, and indications are that medics are more sensitive to deficiency of this element than is subterranean clover.

(iii) *Soil Fertility.*—Over a four-year period a build-up of soil nitrogen has been observed. This will be translated into wheat yields in field and glass-house studies.

Marked changes in soil structure have followed growth of pure grass and pure legume swards and can be correlated with macroorganic matter content of soil. Determinations of possible increases in pore space, infiltration, and percolation rates of water are planned as well as the rate of destruction of structure by subsequent crops.

(*f*) *Pasture Species Trial on Riverina Clay.*—A trial to determine the suitability of a number of legumes for the Riverina Clay environment has been established. Thirty-five leguminous species are involved and the plots will be irrigated under the conditions that apply to a wimmera rye and subterranean clover pasture.

19. Pasture Investigations, Armidale, New South Wales.

(Division of Plant Industry.)

(*a*) *Ecological Survey.*—The field work in connexion with a survey aimed at providing background information on the climate, soils, geology, topography, and natural vegetation of the New England region, as a basis for a rational research programme in the region is almost completed. As part of the survey a detailed census of the plants of the region is being compiled.

(*b*) *Pasture Ecology and Autecological Studies.*—Three years of monthly autecological observations on some 140 native pasture species will be concluded this winter and the results compiled to show the species distribution, phenological behaviour, &c., according to soil type. A recording of the seasonal pattern of nitrogen, sulphur, phosphorus, and calcium in 29 of the more important of the above species has been completed.

Studies of the effects of winter burning of the native pasture have shown that the botanical composition is not markedly affected by this treatment. Dry-matter production by the pasture in the summer following burning was reduced 20 per cent., but by the next summer dry-matter production was comparable with that on unburned control plots. So far the effects of burning have been studied on ungrazed plants. It is now proposed to investigate the effects of defoliation following burning.

Plant competition studies have indicated that with high seedling densities of subterranean clover in the autumn, yields are depressed. There have also been high mortalities of plants with high densities.

(*c*) *Grazing Management Studies of Native Pastures.*—The surplus summer production of native pastures is considered to reduce the grazing value of the pasture in the following winter. An experiment is in progress in which the effect of various summer management practices, including heavy stocking, grazing with cattle, mowing, burning, and the incorporation of clovers, on the winter production of the pasture is being studied. Where a clover stand has been developed merino weaners make good growth throughout the winter. In 1954 a liveweight gain of 76 lb. per acre was made where clovers had been incorporated into the native pasture, whereas the best gain made under any summer treatment involving straight native pasture was 16 lb. per acre.

Following an earlier grazing management experiment on native pastures, in which the deficiencies of this source of grazing were demonstrated, an investigation of the effects on production from sheep on native pasture when offered different proportions of supplementary grazing on sown pastures was commenced. The second year's results, which confirm those of the first year, showed more than double the production per acre, in terms of wool and total liveweight gains, from 57 per cent. of sown pasture (the highest proportion) compared with 4 per cent. of sown pasture (the lowest proportion). During the first year of this experiment it was found that a young Merino sheep, during the age from six to eighteen months, was equivalent to 0.66 of a mature sheep in terms of the grazing pressure exerted on the pasture.

(*d*) *Improvement of Native Pastures.*—The incorporation of clovers into dense native pasture without ploughing has, in general, proved a very satisfactory method of improving the pastures on non-arable land. However, if conditions are dry following sowing, the establishment may be poorer than that obtained from a sowing made at the same time into a prepared seed-bed. In a preliminary study of this question, insecticidal treatment of the clover seed before sowing into native pasture improved establishment when conditions were adverse, and this lead is being followed in a test with a range of insecticidal seed treatmeuts.

Attempts to incorporate commercial forage grasses into native pastures have not been successful in experimental sowings. This is thought to have been due to competition from the native grasses, and further sowings have been made in which this competition is being kept to a minimum by mowing and grazing.

(*e*) *Species and Strains Trials.*—Measurements of the productivity of various grasses and legumes have continued. Higher than average rainfall over the past summer enabled a useful comparison to be made with the production during recent summer seasons, the last three of which have been abnormally dry.

In species survey experiments over a wide range of soils in the New England region the results have shown as wide a variation in production of both grasses and legumes due to soil type as due to climatic conditions. The failure of many legumes to survive on some classes of granitic soil, even with adequate fertilizing, has stressed the importance of soil moisture relationships.

(*f*) *Ley Pastures.*—The productivity of various short-term pastures and their effect on soil fertility is being studied. With three successive crops of oats for grazing yields have declined considerably. Subterranean clover, although one of the highest yielding legumes, has not arrested this decline whereas crimson clover has had a strongly beneficial effect.

(*g*) *Plant Nutrition Studies.*—The survey of the plant nutrient status of the soils of the New England region is nearing completion. Only two of the soils defined in the course of the ecological survey remain to be studied. In general, phosphorus is the nutrient limiting plant growth on the podzolic soils whatever the parent material from which they are derived. When the phosphorus deficiency has been remedied, responses are obtained to nitrogen and sulphur. Basaltic soils, on the other hand, respond principally to nitrogen with smaller responses to sulphur and phosphorus.

In view of the importance of sulphur as a plant nutrient in the region, emphasis is being placed on its study. The severe deficiency in simple sulphur recorded on soils derived from basalt in the Liverpool Range has been shown to extend over 2,500 square miles of basalt country. In only one sample collected from this areas has any response to phosphorus been recorded. Studies of the residual effects of sulphur dressing made to basaltic soils indicate that one-year-old residues are

about one-third as effective in producing plant response as a current dressing given at the same rate of original application. The possibility of replacing some of the superphosphate used with less expensive gypsum is being investigated.

Rock phosphate as a fertilizer for pastures has been investigated. In the second year after application it appeared to be more available to plants than in the first year when, compared with superphosphate, sixteen times as much rock phosphate was required to produce the same growth response.

Investigations of the response of a phalaris-white clover pasture following renovation by ploughing down have shown that although there is a response to this treatment, as measured by total yields of dry matter, the response is not large compared with that obtained from additions of plant nutrients. Soil-exchangeable ammonia and nitrate levels are increased by ploughing, and the availability of sulphur is also increased.

Native leguminous species are subject to conditions of low soil phosphorus, sulphur, and, in the absence of any strong evidence of symbiotic nitrogen fixation, of soil nitrogen too. A study has been commenced, in pot culture, of the response of a range of native legume species to phosphorus and sulphur. The response of the native species relative to white and subterranean clovers will also be recorded.

(*h*) *Clover Nodulation.*—Satisfactory early nodulation of subterranean clover following sowings made on new land is often not obtained. Using strains of root nodule bacteria of proven value under laboratory conditions, an attempt is being made to determine the environmental factors which prevent the rapid multiplication and the infectivity of the culture strain.

20. Pasture and Hydrology Investigations, Deniliquin, New South Wales.

(Division of Plant Industry.)

(*a*) *Ecology.*—(i) *Flora of Riverine Plain.*—The flora of the Riverine Plain has been mapped and described in detail. It would appear that physical soil factors are important in determining the species which grow on the shelf, depression, and puff respectively.

Some of the factors concerned are the soil moisture content at which water becomes available to plants and particularly to seeds; the intensity of soil cracking which influences seed retention, moisture penetration, and the extent to which root systems are damaged; and aeration of the soil.

(ii) *Disclimax Grassland Associations.*—An area originally supporting eucalypt woodland on sandy loams, *Acacia-Atriplex* shrubland on clay loams, and *Atriplex* shrubland on light clays now carried disclimax grassland associations. The various types of association which have developed have been related to topography and texture of the soil and to its water relationships.

(iii) *Wimmera Ryegrass Studies* (Lolium subulatum).—Various problems associated with the growth of this species are being studied in co-operation with Dr. F. V. Mercer, of Sydney University. Determinations of air space in irrigated soils at Deniliquin suggest that low pasture production during winter may be caused by anaerobic soil conditions. An experiment to ascertain the effect of anaerobic conditions and carbon dioxide excess on growth and gross morphology in *L. subulatum* when grown in culture solution is in progress. The effect of anaerobic conditions on the salt respiration and accumulation in the roots of *L. subulatum* will be studied also.

(*b*) *Agronomy.*—The establishment of rice seedlings was increased by 50 per cent. and of stubble-sown subterranean clover from 10 per cent. to 20 per cent. in the four years following rice when gypsum at 2 tons per acre was applied to an alkaline clay with an exchange capacity of 25 mg. equiv./100 g. Treatment increased the calcium : sodium ratio of exchangeable and soluble cations, reduced clay dispersion, and improved soil structure.

Improved establishment of irrigated annual pasture was not reflected in increased yield.

After four years under irrigated Rhodes grass, the water stability of soil had been restored to the level existing before disturbance prior to sowing.

Medic and subterranean clover trials have been established on various soil types to establish the suitability of species and determine cultural practices useful for establishment.

Summer watering of phalaris-subterranean clover pastures has resulted in a twofold increase in plant material. There was severe depression of the clover and phalaris growth was coarse and unpalatable. A regular grazing treatment has been introduced in an attempt to contol this coarse summer growth.

(*c*) *Pasture Utilization.*—Experimental results from trials to investigate mathematical relationships for organic matter digested and feed nitrogen intake with faecal nitrogen agreed with Raymond's equation. The constant for regression found by Lancaster ($0.8 \pm .081$) was not found to hold in the Deniliquin work, where the constant was 0.948 ± 0.041 in one trial and 0.945 ± 0.019 in another.

The effect of rationing intake on efficiency of utilization of a paspalum-cocksfoot-white clover pasture by Merino lambs was investigated during the autumn of 1955. Body weights per acre were inversely related to stocking rate, but wool production per head per acre was not related in the same way. Maximum production of wool per head was at the lowest stocking rate whereas maximum production per acre was at the highest stocking rate.

(*d*) *Plant Introduction.*—A number of new introductions are being investigated for suitability to the area. Natural selection of phalaris strains is being studied in a mixed sward, and seed multiplication of *Panicum coloratum* and *Poa iridifolia* for future sward trials is in progress.

(*e*) *Plant Nutrition.*—Following observations of poor growth and abnormal colouring of lucerne on several soil types, a series of major and minor element trials have been established at three sites in the area.

(*f*) *Genetics.*—(i) *Natural Selection of Subterranean Clover.*—The aims of studies involving mixtures of strains and mixtures of hybrids are (1) to estimate the value of hybridization, in self-fertilizing species, as a technique for releasing a larger amount of genetic variation than could be obtained from a mixture of the parents, as a means of increasing the chance of producing strains adapted to new environments; (2) to study the changes in both means and variances of morphological and physiological characters in the hybrid clover plots subjected to different environmental treatments, which study may elucidate the adaptive significance of some of the characters; (3) to develop a strain, or strains, of subterranean clover adapted to more arid conditions than at present can support subterranean clover as a pasture species.

Trials have been established at the Falkinder Memorial Field Station, Berrigan, Euston, and Tooleybuc.

(ii) *AF2 Lucerne Species and Strain Trial.*—Two strains of creeping lucerne are being compared with the ordinary "Hunter River" variety to determine adaptability to the environment. Various measurements for size and yield are made regularly and flowering data are being collected.

Results to date indicate the superiority of creeping lucerne over the "Hunter River" variety for spring, summer, and autumn growth on heavy soil at Denili-quin. Production of these strains will be compared under sward conditions at the Falkinder Memorial Field Station.

(*g*) *Hydrology.*—(i) *Vapour Movement in Soils.*—Determination of adsorption isotherms for sand separates ranging from 0.07 to 1.0 mm. was undertaken. The unsatisfactory nature of containers used at high temperatures prevented conclusive results being obtained.

(ii) *Tilting Test Plot.*—It has been shown in preliminary experiments that a flume of 1 ft. width will give a satisfactory pasture sward for this work.

21. Pasture Investigations in Western Australia.

(Division of Plant Industry.)

(*a*) *Grazing Management of Annual Pastures.*—A trial at Perth, established in 1949 for the comparison of continuous and autumn-deferred grazing on an annual-type subterranean clover pasture, has been terminated. A stocking rate of 2.2/3 wether sheep/acre/annum approaches the maximum desirable figure for this type of pasture. Ripgut brome grass (*Bromus rigidus*), always the dominant grass on autumn-deferred treatment, became the major grass constituent on the continuous grazing treatment in 1954; Wimmera ryegrass failed to persist. Chemical analyses have demonstrated the high protein content of cape-weed relative to grass during summer. Further evidence on relative consumption has confirmed that palatability of subterranean clover during the growing season does not differ substantially from that of cape-weed or annual grass.

(*b*) *Studies on Perennial Grasses.*—(i) Phalaris tuberosa.—Wide spacing, especially with cultivation between rows, has consistently produced higher yields per unit area than narrow spacing (7 and 21 inch rows), until 1954 when there was no evident difference. While a further trial involving four strains of *Phalaris tuberosa* with and without fertilizer nitrogen has not shown marked differences in strain performance, the associated volunteer annuals have responded to applied nitrogen to at least the same degree as the sown perennial grass.

(ii) *Other Pasture Grasses.*—A trial at Perth, in which heavy intermittent grazing was imposed on three grasses—*Hyparrhenia hirta, Phalaris tuberosa,* and *Ehrharta villosa*—over a four-year term has demonstrated clearly the potential value of *Hyparrhenia* as a pasture grass. Germination is a serious barrier to economic development and studies on this problem are in progress. The perennials *Hyparrhenia hirta, Phalaris tuberosa, Ehrharta calycina,* and *Oryzopsis miliacea* are being studied under intermittent grazing both at Perth and Kojonup, whilst *Phalaris tuberosa* and *Ehrharta calycina* are now under rotational grazing at Kojonup at a stocking rate of two sheep/acre. The polycross technique is being used to build up a non-shedding strain of *Ehrharta calycina.* Some difficulty was experienced in obtaining satisfactory survival of spring-sown *Phalaris tuberosa* during the first summer.

(*c*) *Species and Strain Trials with Annuals.*—(i) *Subterranean Clover.*—Strain studies both with single-spaced plants and swards are continuing. A sward trial involving fifteen strains and established in 1950 has now become grass-dominant. Since this factor must be reckoned with in long-term strain assessment, the trial will continue for at least a further two years. Work is continuing on a "bulk" sward trial sown in 1953 and containing 52 strains.

(ii) *Brome Grasses.*—These grasses, in particular soft brome (*B. mollis*), appear promising for pasture use. Preliminary information of performance under continuous grazing is being sought on eight strains of soft brome and also on a number of other species.

(iii) *Cereals.*—Variety trials with wheat, oats, and barley have been continued at Kojonup. During the 1954 season, barley was superior to oats in winter production, but inferior in grain production. The highest grain yields were recorded in Avon and Orient. The mid-season wheats were slightly better than Gabo and Insignia 49 with early planting, although the latter two varieties were oustanding with late planting.

(*d*) *Plant Nutrition Studies.* — (i) *Pot-culture Trials, Perth.*—Studies in phosphorus utilization by annual legumes (lupins, barrel medic, and Dwalganup and Bacchus Marsh subterranean clover) are in progress using superphosphate, tricalcium phosphate, and rock phosphate as sources. In view of the importance of the phosphorus "fixation" problem, work is in progress in which superphosphate is "incubated" in two soil types under various conditions.

(ii) *Field Trials, Kojonup.*—The influence of season on zinc response in three strains of subterranean clover is still under investigation.

A comparison of annual applications of superphosphate with a single initial dressing is continuing on two contrasted soil types. Percentage phosphorus uptakes have been markedly lower on gravelly lateritic as compared with sandy soil. Results to date indicate no advantage of annual over biennial applications of superphosphate.

The percentage phosphorus uptake has declined progressively with superphosphate, but has remained almost uniform with rock phosphate over three years in a trial designed to study residual phosphate effects.

Sulphur trials have been continued, with the object of clarifying the relationship between cultivation and sulphor response.

(*e*) *Ecology of Annual-type Pastures.*—Studies of factors influencing fluctuations in the botanical composition of Mediterranean annual-type pastures are being continued. The main experiment concerns phosphate season interactions. Long-term seasonal effects are also being examined. Silver grass and subterranean clover seedlings showed low survival in comparison with capeweed, *Erodium botrys,* and ripgut brome grass under drought conditions following February rains. The effect of time of seasonal opening on composition is being studied under controlled conditions at Perth. Ripening of seed after harvest appears to be an important factor in this connexion. The phenomenon has been demonstrated for a number of volunteer annuals grown under Western Australian conditions.

(*f*) *Soil Fertility Investigations.*—Some results are now available from long-term field trials commenced at Kojonup in 1952. Increase in total soil nitrogen was not related to production of subterranean clover, the growth of which was controlled largely by phosphate supply. The rate of build-up was almost as great on the extremely phosphorus-deficient clover plots as on those adequately supplied. Moreover, this rate was substantial, even during the year of sowing, viz., *c.* 100 lb. total nitrogen/acre-4 in. Further work on this problem is in progress.

The influence of seeding rate of subterranean clover on build-up of soil nitrogen was not pronounced. This finding is of some interest in view of the contrary evidence of early fertility build-up elsewhere in Australia.

A number of related trials are in progress, including the influence of soil type on fertility build-up under subterranean clover pasture, and the effect of the grazing animal *per se.*

Two experiments have been in progress since 1952, in which wheat is sown continuously on areas previously in clover pasture. In no instance has the second-year crop exceeded the first in yield, and fertility has declined rapidly with each succeeding wheat crop.

22. Pasture Investigations in South-eastern Queensland.

(Division of Plant Industry.)

(*a*) *Coastal Lowlands.*—(i) *Ecological Survey.*—The main objective of gaining an understanding of the overall environment of the region and of subdividing it into its component natural units of geology, topography, soils, vegetation, and climate, has now been almost attained. Similar country to the coastal lowlands of southern Queensland extends southwards almost as far as Sydney. Thus studies of nutrient deficiencies and pasture mixtures in progress may have a fairly wide application.

(ii) *Pasture Species and Mixtures.*—Work is concentrated at Beerwah on two soil types that are typical of large tracts of country. Most attention is being paid to a relict sandy laterite soil. After nutrient deficiencies of major and minor elements were corrected, the best grass species under grazing were *Paspalum dilatatum, P. commersonii, Brachiaria purpurascens,* and *Chloris gayana,* and the best legumes were white clover and *Phaseolus lathyroides.* A total grazing equivalent of 4.54 sheep per acre per annum has been obtained.

Two species of legumes which are giving good results are *Indigofera endecaphylla* and *Desmodium uncinatum,* and these have given total yields of dry matter per acre over the year of 54 and 20.5 cwt. respectively. The normal growth of most legumes is now being obtained owing to the right application of *Rhizobium* strains.

Calcium dressings have been shown to be essential for successful clover growth on these coastal soils.

Eight grasses were each sown with three legumes, *I. endecaphylla, D. uncinatum,* and *Stylosanthes bojeri,* and the mean yields of dry matter of all eight grasses with the three legumes were respectively 32, 30, and 17 cwt. *I. endecaphylla* produced the most nitrogen and the return from the grass growing with it was of the order of 20 lb. of nitrogen per acre.

The work at Caboolture with the *P. dilatatum* sward on a peaty sand has shown a low recovery (30 per cent.) of applied nitrogen in the herbage, but a dressing of 400 lb. N per acre gave a three and a half-fold increase in yield of dry matter from 2,000 to 6,900 lb. per acre. Plots well supplied with nitrogen were able to withstand frequent cutting and the growing season was also extended.

(iii) *Plant Nutrition.*—Some of the fertilizer trials are now in their third season. Plots receiving comprehensive fertilizer treatment support a good pasture of white clover and *P. dilatatum.* This pasture is dense, productive, and uncontaminated by invading species. The fertilizer treatment necessary to produce this result consists of superphosphate, lime, potash, and copper. Zinc and molybdenum play a minor role. The efficiency of the clover in supplying nitrogen is reflected in the high yield of grass. Supplementary dressings of superphosphate and potash at least are necessary to maintain the clover at a high level of production.

New experimentation on a forest soil has been initiated and excellent growth of white clover has been obtained, but as with the other soil, this has occurred only where comprehensive fertilizer treatment has been used—viz., phosphorus, calcium, potassium, copper, sulphur, and molybdenum.

There is no doubt that legume and grass species can be established on these soils provided adequate plant nutrients are added in suitable combination. The next important step is to maintain these pastures at maximum production. It is anticipated that maintenance will be high in at least the first few years. However, with the use of the grazing animal a more stable cycle of plant nutrients may be established.

Differences in response to plant nutrients by different plant species have been found. A programme of research into the critical values of nutrients for the species involved and also into the critical levels for the appearance of symptoms of nutrient dificiency and excesses has been started.

Pot culture experiments have shown that results obtained at Beerwah (50 miles north of Brisbane) may be applicable to other soils in the coastal region —e.g., Maryborough (150 miles north of Brisbane). Qualitatively the results agree, differing only in degree.

(*b*) *Spear Grass* (Heteropogon contortus) *Region.*—Experiments are in progress at "Rodds Bay", "Brian Pastures", and Lawes. Of fourteen grasses and nine legumes which have been tried in mixtures and pure swards, the most successful grasses were *Paspalum scrobinculatum* and *P. plicatulum,* and the most successful legumes *Phaseolus lathyroides, Stylosanthes gracilis,* and *S. bojeri.* The mean yield of dry matter of eight grasses was 19.6 cwt. per acre without a legume, and 29.5 cwt. per acre with *P. lathyroides. P. lathyroides* increased grass yield by 9.9 cwt. and its own yield was 9.8 cwt., giving a total increase of 19.7 cwt. of dry matter. *S. gracilis* and *S. bojeri* had a similar but smaller effect.

Studies with soil from the experimental area at "Rodds Bay" have indicated that phosphorus, sulphur, and molybdenum are needed for the growth of *P. lathyroides.* The main deficiency is phosphorus. Experiments with other soils have also been done. On a granitic soil at "Takilberan Station", near Gin Gin, lucerne established but subsequently died in the absence of calcium carbonate. An addition of 10 cwt. per acre of calcium carbonate resulted in growth and persistence of lucerne. In pots of this soil *P. lathyroides* responds to phosphorus, calcium, and molybdenum.

At "Brian Pastures", near Gayndah, work has commenced on soil derived from granite. *P. lathyroides* on this soil in the field exhibited an unusual type of chlorosis which pot experiments have indicated may be due to lack of sulphur.

(*c*) *Sown Pastures on Black Soils (Cooper Laboratory, Lawes).*—(i) *Lucerne and* Paspalum commersonii (*Scrobic*).—With scrobic an increased yield of herbage is obtained from cultivated rows compared with swards. This advantage is not derived from conserved soil moisture, since this is never reduced to a critical level. The production from a sward of scrobic can be raised to relatively high levels by the application of sulphate of ammonia or the inclusion of an annual legume (*Phaseolus lathyroides*). Undergrazing a mixed pasture of scrobic and *P. lathyroides* is difficult to maintain, and it becomes virtually a pure stand of grass within two years.

Where grass and legume are maintained in separate pure stands and the animals are allowed free access to each, it is possible to keep both the animals and the stands of pasture in good condition. Such a technique might allow the use of species that have been discarded because of inability to grow in association.

(ii) *Digestibility of Selected Subtropical Pasture Species.*—Most subtropical grasses are very low in protein during the winter and it has been shown that any grass with less than 6 per cent. crude protein will not satisfy the protein maintenance requirements for adult sheep. The work has emphasized the importance of suitable grazing legumes

particularly during the winter and early spring periods when pasture growth is slow and quality poor. In addition there is a need for subtropical grasses with high digestibility and potentially high intake when supplementary protein is provided. Two grasses, *P. commersonii* and *Urochloa pullulans*, are likely to meet these requirements; e.g., when sheep were fed poor-quality *P. commersonii* hay, the intake of non-protein foods was below their maintenance requirements for a period of approximately four months, but a small supplement of green lucerne (crude protein 19 per cent.) increased dry matter intake by 300 per cent. Techniques in the indirect measurement of digestibility and intake of pasture forages are being investigated.

Faecal nitrogen, chromogen, lignin, and crude fibre have been used as markers, and all have so far proved unsatisfactory for subtropical grasses. The data show a good correlation between the total daily output of faecal nitrogen and the dry weight of feed ingested.

(*d*) *Sown Pastures on Sandstone Ridge Soils (Cooper Laboratory, Lawes).*—The pasture development studies on the sandstone ridge soils of the Lockyer Valley have been continued. The soil on the Bundamba series has shown response to phosphorus, molybdenum, calcium, and copper, while the soil on the Marburg series has shown similar response, but to a much smaller degree. With *Phaseolus* the main response is to phosphorus and molybdenum, but with *Medicago* species lime plus the proper strain of *Rhizobium* has given a spectacular effect.

(*e*) *Plant Biochemistry.*—An investigation of the toxic principle in *Indigofera endecaphylla* is in progress. Overseas workers have identified β-nitropropionic acid as a toxic constituent of this plant and the work here has shown that this substance occurs in all the strains of *I. endecaphylla* grown. A chromatographic technique was developed for the detection and semi-quantitative estimation of small amounts of this acid in *I. endecaphylla*. Leaves at the early flowering stage contain 0.08 per cent. β-nitropropionic acid on a dried weight basis.

Work with the toxic alkaloid mimosine, which is found in *Leucaena glauca*, has shown that paper chromatography can be used as a rapid and sensitive method for its detection. It is proposed to follow the variation in mimosine content within and between strains of *L. glauca*.

Work on the nitrogen metabolism of *I. endecaphylla* and white clover is being done, using an 80 per cent. ethanolic extract. Amino acid content is being examined using two-dimensional paper chromatography.

Lignin has been used as an "indigestible tracer" for the determination of digestibility in feed intake with the grass species *Paspalum commersonii, Panicum maximum*, and *Urochloa pullulans*. Sheep were used as the test animal. There was a low recovery of lignin in the faeces. The results of three digestion trials indicated that lignin is not a suitable marker for trials with subtropical species.

A technique has been developed for the rapid determination of calcium, potassium, and phosphorus on a single digest of plant material. Suitable aliquots are taken and the potassium is estimated by flame photometry, calcium by complexometric titration, and phosphorus colorimetrically. The scope of analyses carried out for colleagues in other sections has been widened to include the determination of sulphur, manganese, molybdenum, and boron.

The effect of potassium deficiency on the free amino acid content of *Phaseolus lathyroides, Desmodium uncinatum*, lucerne, and white clover has been studied. Putrescine has been detected chomatographically in each of these plants. In addition, the amount of dicarboxlic, aspartic, and glumatic acids in the potassium-deficient plants was very low, while the amide content was higher than that found in the normal plant. A striking effect of the addition of potassium, at luxury level, to the free amino acid content of the potassium-starved plants is the very quick build-up of the dicarboxylic acids. This work is being extended to include the effect of deficiencies of some other essential elements on the free amino acid contents of plants. Pronounced effects have been recorded in the case of both magnesium and sulphur deficiencies.

This approach to the study of metabolism will include the measurement of other metabolites such as organic acids, α-keto-acids, and amines, and some progress has been made in the development of techniques for their measurement. White clover is at present being used as a test plant in this work. The effects of deficiency of potassium, magnesium, sulphur, iron, manganese, and zinc are being examined.

(*f*) *Legume Bacteriology.*—Field collections have been made of nodules from miscellaneous native and cultivated leguminous species, and the bacteria subsequently isolated in pure culture. A collection of cultures has now been amassed from which to draw experimental material as required.

Some time has been devoted to techniques of testing *Rhizobium* strains for effectiveness, particularly as the standard test host for most of the strains required in a subtropical area is the cowpea, which grows too large for manipulation in tubes. The standard United States Department of Agriculture technique of a dolomite-sand mixture irrigated with acid culture solution has proved unsatisfactory for many tests. A rapid screening technique for isolates from nodules has been developed in which vermiculite in tubes is used as a growth medium and *Phaseolus lathyroides* as a standard host instead of cowpea.

Work on nodulation habits and effectiveness of *Stylosanthes* spp., particularly *S. sundaica* and *S. gracilis*, has been commenced in view of the potential importance of *Stylosanthes* as a legume in spear grass areas.

(*g*) *Plant Breeding.*—The legumes being grown at Strathpine Experiment Station and elsewhere have been examined for their field resistance to the "little leaf virus" which is allied to "tomato big bud" and "witch's broom" of lucerne. The more promising pasture legumes such as *Phaseolus lathyroides, Indigofera endecaphylla*, and *Leucaena glauca* are field resistant to "little leaf virus". *Desmodium uncinatum* is susceptible to the virus but the strain (C.P.I.) 8990 has the ability to grow away from the virus, and *D. intortum* is quite resistant. Most of the genera contain both resistant and susceptible species, so that material is available for any breeding project on "little leaf" resistance.

The mode of pollination has been studied in a range of subtropical legumes by bagging experiments and the dissection of buds at different stages of development. *P. lathyroides* is closely self-pollinated and pollination occurs when the buds are relatively small. No variation has been found as yet in this species. *D. uncinatum* and *I. endecaphylla* are two species in which tripping takes place so that both self- and cross-pollination can occur. A high percentage of humidity of approximately 90 per cent. is required for the pollination of seed-setting in most of the subtropical pasture legumes.

A breeding programme is in progress to develop strains of *I. endecaphylla* which are free of the toxic principle of β-nitropropionic acid. A cross has been made within the genus *Phaseolus*. This will give a variable population for selection.

In *L. glauca* most of the plants tend to be of the same type but recently two variants have been found. These will be used for crosses with the common type.

The *Phalaris allopolyploid* has proved to be of some promise and selection of the best perennial types is proceeding. Other grasses which have been studied are included in the genera *Paspalum, Setaria,* and *Digitaria.* Apomixis still prevents progress in *Paspalum,* but both *Digitaria* and *Setaria* are cross-pollinated so that selection work can proceed in these. Breeding work has also been done on lucerne. Rhizomatous types have been developed and these are being multiplied for further testing. With white clover a study is being made of a large number of strains with a view to developing types better adapted to coastal conditions.

23. Biophysical Research.

(University of Tasmania.)

(i) The investigation of the electric fields associated with growing plant tissue is continuing. Using automatic recording apparatus developed in the laboratory, attention is being mainly directed to the periodic variations in electric pattern which are sometimes observed to be associated with a growing root. A recording growth meter has also been constructed which detects growth of a rapidly elongating root in a few seconds.

(ii) A study has been made of the electric properties of large plant cells with particular reference to the potential difference across the tonoplast and plasmalemma. This has been done by the use of microelectrodes implanted in the cell. There is practically no potential difference across the tonoplast, which is contrary to some theories of the origin of these electric fields.

(iii) Studies of the regeneration of several plant apices have been conducted in the laboratory. Apical fragments as small as 0.001 mm^3. (about 600 cells) have been found to regenerate into complete plants when cut off and then replaced on the stem.

24. Fodder Conservation.

(Plant Fibre Section.)

(*a*) *Chemical Investigations.*—Routine methods of chemically evaluating fodder have been used to examine some hundreds of samples from various haymaking trials. Concurrently with the routine analyses for crude protein, crude fibre, crude fat, ash, nitrogen-free extractives, and carotene, a study is being made of the effects on the results of different methods of preparation of the samples including drying, grinding, and storage.

More detailed methods of chemical analysis are now being examined, including the determination of such constituents as methylene chloride solubles, benzene alcohol solubles, uronic anhydride, lignin, pentosans, and pectins.

(*b*) *Physical Investigations.*—Studies have been initiated to provide a basic background for investigations of haymaking. These include work on moisture content equilibria of fodder plants, drying curves for different components of plants, mechanical methods of separating the fragile from the tougher portions of plants, and the mechanical strength properties of various pasture species at different stages of maturity.

(*c*) *Microbiological Investigations.*—This work is related primarily to silage fermentation. So far, it has been concerned mainly with the factors influencing the development of bacteria producing lactic acid from fodder crops ensiled in laboratory silos, and by means of a special test-tube technique. During the work predominant strains of the lactobacilli have been isolated in pure culture for investigation of their morphological, cultural, and physiological characteristics.

(*d*) *Haymaking Investigations.*—The Plant Fibre Section has co-operated with the School of Agriculture of the University of Melbourne in haymaking trials at the State Research Farm at Werribee and at the Commonwealth Scientific and Industrial Research Organization Field Station at Cobram. The object of the trials has been to determine the effects of time and method of raking on the characteristics of the windrows formed, their rate of drying, mechanical losses, and change in chemical composition.

Some preliminary experiments have been carried out at Tooradin on the value of crushing fodder crops with rollers after mowing.

(*e*) *Ensilage Investigations.*—Considerable work was entailed in developing laboratory silos which would permit the accurate control of the various factors which may influence the production of silage. A satisfactory unit has now been designed and 48 of these are now available for investigational purposes. Preliminary trials with perennial ryegrass, clover, and lucerne have shown, amongst other things, the advantages of using chopped material in silage making.

The establishment of satisfactory methods of sampling and analysing silage for such constituents as volatile bases, volatile acids, and lactic acid has proved more difficult than was anticipated.

25. Evapotranspirometer.

(Central Experimental Workshops.)

In collaboration with the Irrigation Research Station, Griffith, equipment has been developed at the Central Experimental Workshops for the measurement of evapotranpiration from a growing crop. Measurement by direct weighing has been used in preference to the alternative soil tank method, and the aim has been to produce a simple and inexpensive piece of equipment, capable nevertheless of reasonably high accuracy, rather than an elaborate and extremely sensitive apparatus.

Although the equipment by its very nature has some inherent features which militate against extreme accuracy, it has been possible in field tests to detect with it changes of weight to an accuracy of rather better than 0.2 per cent., corresponding to about 0.013 per cent. of the total weight of the loaded equipment. A description of the apparatus will appear in a forthcoming issue of the Australian Journal of Agricultural Research.

26. Nursery Thresher.

(Central Experimental Workshops.)

A requirement has existed for many years for special machinery for harvesting and threshing seeds from small experimental plots of pasture grasses and cereals. A number of machines have been developed in the past at different research establishments, mainly on the basis of trial and error, and mainly for use with cereal crops. The present need within the organization for machines of this type is largely for use with grasses, where the problems involved are rather different from those associated with cereals, owing to the smaller seeds, the stronger stems, and frequently the greater difficulty of threshing.

As part of a programme for the development of machines for the Division of Plant Industry, an experimental nursery thresher has been constructed at the Central Experimental Workshops: details of the machine are given in Central Experimental Workshops Internal Report No. 17, of April, 1955, "Nursery Harvesting and Threshing Machinery for Pasture Grasses and Cereals". The aim has been to build a machine which will handle a wide variety of grasses, including clovers and medics, which up till now have generally had to be rubbed out by hand. Tests carried out at Canberra have shown that this aim has been largely realized, and it is understood that the division now intends to have a number of additional similar machines manufactured.

IV. IRRIGATION.

1. General.

The production of crops under irrigation requires specialized techniques, and the continued application of water to the soil can result in problems not encountered in dry-land agriculture. The deterioration of land under irrigation is a world problem of great magnitude.

For the study of ways in which irrigated land can be made to keep its fertility, and waterlogged land can be reclaimed, the Organization has two Irrigation Research Stations: the Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, on the Murray River, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales. The work of these two stations is reported in this chapter.

Research into soils and their behaviour under irrigation has been carried out at both Merbein and Griffith in close co-operation with the Division of Soils (*see* Chapter II.).

Studies of irrigated pastures are carried out at Deniliquin, New South Wales, by the Division of Plant Industry (*see* Chapter III., Section 20), and other investigations of irrigation techniques for northern tropical areas are carried out by the Land Research and Regional Survey Section at the Kimberley Research Station near Wyndham, Western Australia (*see* Chapter XI., Section 3).

Irrigation Research Stations.—During the current year, the Organization's interests at Merbein and Griffith have been amalgamated. Mr. F. Penman is now responsible for the direction of the joint Irrigation Research Stations as Senior Officer-in-charge. This move is expected to result in more effective investigation of irrigation problems by concentration of the resources of each station on particular aspects.

The Irrigation Research Stations serve an irrigated area of orchards, vineyards, and vegetable farms totalling 100,000 acres producing an estimated £15,000,000 per annum. In addition the stations are interested in more than 250,000 acres of irrigated rice, wheat, and pasture land producing more than £6,000,000 per annum. An important problem of irrigated lands is that of nematode infestation of crops. Knowledge of Australian nematology was augmented considerably by the appointment to Merbein of Dr. J. W. Seinhorst, of the Phytopathological Institute, University of Wageningen, Holland, as a Research Fellow for six months. During his visit, demonstration of new nematological techniques was given as part of a week's discussion group arranged for interested officers of State and Commonwealth Departments and Universities.

Other visitors to Merbein were Professor H. P. Olmo, Professor of Viticulture, University of California, and Professor J. Thorpe, formerly of United States Soil Survey. Messrs. S. A. R. Alljaffree, Director of Lands, and Raja Aszam, Commissioner, of Malaya, visited Griffith Station under the Colombo plan.

A report has been made to the Commonwealth, New South Wales, and Victorian governments recommending that a future policy for dried vine-fruit growing areas of the mid-Murray. These areas include the irrigation settlements of Goodnight, Koraleigh, Nyah, Tresco, and Woorinen. The Merbein Station represented the Commonwealth Government on the committee, set up in 1953, charged with the preparation of this report.

Commonwealth representation on the Irrigation Production Advisory Committee now includes the Senior Officer-in-charge, Irrigation Research Stations, who is also a member of the Australian National Committee of the International Commission on Irrigation and Drainage.

Formed to promote the investigation into the deterioration of land by waterlogging and soil salinity in portion of the Swan Hill flats, the Swan Hill Irrigators' Research Committee has acquired its own property. This farm will be available for continual use by investigating authorities. The Merbein Station is represented on this committee.

The Griffith Station continues as a co-operative concern in which the Organization and the Water Conservation and Irrigation Commission of New South Wales are partners. The Commission makes an annual contribution towards working funds for the station. Co-operative investigation between the two bodies has begun on the assessment of behaviour of tile drainage installations recently established in the Murrumbidgee Irrigation Areas (M.I.A.).

Close relationships continue between the Merbein Station and the dried-vine fruits industry. Annual contributions of funds are made by the Commonwealth Dried Fruits Control Board, the Mildura Packers' Association, Co-operated Dried Fruits Sales Proprietary Limited, and the Nyah-Woorinen Inquiry Committee. Both Merbein and Griffith Stations have co-operated during the year with the Division of Meteorological Physics in frost control investigations. Arrangements for joint participation in field days and in investigations on fruit drying were made between the Merbein Stations and Departments of Agriculture in Victoria and New South Wales.

2. Merbein.

(*a*) *Irrigation, Soil Preservation, and Reclamation.*—Drainage investigations at Renmark were continued during the year, with further ground-water observations and with soil and vine sampling. The general flow pattern for the part of the district covered by the piezometer grid is now well established, so also is the seasonal cycle of water levels and the influence of several different methods of drainage. The heavy soils are now known to have too low a vertical permeability to be generally suited to drainage by lowering the water pressure in the underlying sands. Lighter soils have responded where there is sufficient lowering of water levels in the upper part of the sand bed.

Where the lighter soils have a clay layer separating them from the main sand bed, lowering of the pressure level in the sand as by pumping from bores or from spear-point batteries is less likely to be successful. However, during the past year several drains have been operating successfully in a Bookmark loam, with a clay layer a few feet below the drains, the files being supported by wooden battens and surrounded by a screen of coarse sand or fibrous material. These drains have given a rapid lowering of the water-table without becoming clogged by fine sand.

During the year the drilling equipment was transferred from Renmark to Swan Hill, where some of the irrigated pastures on the river flats suffer waterlogging and salinity troubles. Work has begun on the farm controlled by the Swan Hill Irrigators' Research Committee. Test wells have been installed there for water-table readings, and soil permeability measurements have been made using the auger-hole method. Deeper borings have found saturated sand under most of this farm, and piezometers have been placed in these deep holes.

(*b*) *Land Use.*—New land is still being developed in the Murray region for irrigated pastures and horticulture, and the Research Station has advised on suitability. Soil surveys covering a total area of 880 acres have been carried out during the year in New

South Wales for horticultural group settlements, and 450 acres in Victoria for irrigated pastures for a large pastoral company.

The Merbein Station representative has been Chairman of the Wakool Land Use Committee during the past year. Extension of the activities of this Committee to embrace other areas such as Denimein and Deniboota has been agreed upon, if landholder associations in such areas so desire. The chief concerns during the year have been the development of dangerously high water-tables on portions of the Tu'la settlement and consideration of land use in relation to this problem.

One of the problems of land use is the renovation by growth of pastures or lucerne of Woorinen land on which vine growing has been abandoned. Two sites are being considered; sown down nearly seven years ago, one will be planted to fruit trees this spring, the other may be kept under grass for some years longer.

(*c*) *Horticulture.*—Sultana bud examinations in May, 1954, revealed that 62 per cent. of buds were fruitful—a very high figure. This was verified by examination of the vines after bud burst in spring.

A severe hail-storm in November caused extensive damage to sultana vines in some parts of Sunraysia. Differential pruning treatments applied just after the hail-storm showed that canes from lateral continuations arising from shoots spurred to bud positions six to ten yielded 55 per cent. fruitful buds compared with 34 per cent. from other treatments. The sultana bud examination on normal vines in May, 1955, has shown 52 per cent. fruitfulness which, with normal weather conditions, will result in a good crop in autumn, 1956.

Fruitfulness studies in sultanas have proved to be a reliable indication of district yield which is currently worth around £6,000,000 per annum. Yields of sultanas appear to be related to hours of bright sunshine, which have been recorded at the Research Station since 1931. There is a correlation coefficient of 0.76 for yield in Merbein district and sunshine for September, October, and the first half of November fifteen months prior to harvest and of -0.515 for yield and sunshine for the same period 27 months previously.

The sultana pruning trial with constant numbers of buds per vine and varying numbers of canes of varying lengths has been terminated. Canes of fourteen and eighteen buds did not significantly differ in yield. In years of high fruitfulness, yield was significantly depressed when canes were 25 buds long.

A preliminary trial on the prevention of splitting of currant berries due to rain was inconclusive.

Improvement of sultana vine growth and yield through soil fertility treatments on heavy soils is being further investigated at Woorinen and Koraleigh. Two six-year trials at Woorinen revealed no responses to gypsum, sulphur, or a "no cultivation" treatment with weeds controlled with oil spray. By contrast, a similar "no cultivation" treatment improved yield at Koraleigh, where gypsum did not increase yield but made the soil easier to work.

A "no cultivation trial" trial at the Research Station which includes oil spray for weed control and white clover sod has resulted in no yield increases through these treatments.

A trial comparing other weed killers against fuel oil gave the interesting result that pentachlorphenol in creosote increased yield about 15 per cent.

Tick beans are commonly grown in irrigated vineyards for green manure. Nine sites were examined in the Merbein district to test the response of tick beans to superphosphate. While phosphorous content of the tops was increased from 0.208 to 0.220 per cent. of dry matter, in all but one site there was no growth response. Limited work suggests that a figure below seven parts per million for "carbon dioxide available" phosphorous in the soil indicates a need for adding phosphates.

Despite local farmer opinion that downy mildew disease is killed by air temperatures above 100° and up to 110° F. it was noted that the disease spread further following a later rain. Laboratory examination showed that these temperatures did not affect the fungus during incubation nor at a subsequent vegetative stage.

Various fungicides were tried to protect sultanas on the vines from mould: "Zineb", "SR.406", colloidal sulphur, calcium propionate, "Shirlan", "Quat", and "Cetavlon" as sprays; and "Zineb" and sulphur, "SR.406", and sulphur alone as dustings. All failed to restrict mould damage in this very difficult harvest period.

Citrus investigations have included the application of hormone pastes to the styles of freshly opened flowers, but it failed to induce better set. Defoliation of flowering shoots about four weeks before flowering seemed to reduce the set of fruit. Spraying of young spring growth with maleic hydrazide (500 p.p.m.) to delay flowering had no effect.

(*d*) *Plant Nutrients.*—The manuring of the sultana vine and the relation of nutrient levels to yield are studied in several field trials and in the laboratory. The only response is to nitrogen but this response is not great and is by no means consistent from one year to another nor from one trial to another. No conclusive results have been obtained either by varying the amount of sulphate of ammonia or its time of application—autumn, early spring, or late spring. Further, it has been hard to draw conclusions from field trials because of the variability and perennial nature of the sultana vine.

Urea as a foliage spray for sultana vines has been compared with ground application of sulphate of ammonia, but neither has given a response in the second year of the trial, although leaf nitrogen is increased. Quite high concentrations of urea spray could be used without leaf damage.

There is little correlation between sultana leaf nitrogen and yield for either the current or the following year, although nitrogen applications to the soil increase the nitrogen content of both lamina and petiole. To see if the N-P-K balance can be correlated with yield, phosphorus and potassium content of leaf samples from field trials are being determined.

(*e*) *Vegetables.*—"Krilium" as a soil improver in tomato glass-houses has been under trial for two years on a Curlwaa loam, but there have so far been no significant differences in yield or early ripening. A further trial was laid down last year on a heavier soil.

Work on tomato hybrids resistant to both root knot nematodes and to fusarium wilt has been continued, and progress has been made towards obtaining highly resistant varieties with desirable field agronomic qualities. Selections are also being made to develop a tomato with the agronomic qualities required in glasshouse culture.

(*f*) *Nematology.*—Peanuts and *Crotalaria spectabilis* in a field management trial were not very effective in reducing nematode population in one season, as revealed by counts of larvae from soil samples. Susceptible and resistant tomatoes were grown in this trial to develop field ratings for the field management treatments. Yields of susceptible tomatoes were highest from plots which had summer clean fallow plus winter barley for three seasons. Resistant tomatoes cropped well on all plots but showed heaviest nematode infection on plots which had carried resistant tomatoes for three seasons.

Nematode investigations were carried out in vineyards and orchards during a five months' visit by Dr. Seinhorst, Wageningen, a Research Fellow. Investigations of declining vines in the district revealed that root knot nematode and citrus nematode were widespread. In addition, two species of *Pratylenchus* (root lesion nematode) were found attacking vine roots. The root knot nematode present in this area appears to be *Meloidogyne javanica*.

3. Griffith.

(*a*) *Soil Salinity.*—Redistribution of salt in the soil following irrigation often leads to toxic accumulation of soil salt and constitutes a serious problem on the Murrumbidgee Irrigation Area. Studies have shown that this salting is associated with certain land forms. The recognition of the land forms liable to salting is important in developing new land for irrigation. The composition of the soil salt and the variation in that composition with depth is also found to be associated with the land form. This helps in explaining the development or origin of the land form (pedogenesis), and suggests methods for prevention of salt accumulation and remedial measures.

It has also been found that salt accumulation is related, to some extent, to the crops grown and the cultural practices adopted.

(*b*) *Horticulture.*—The factorial experiment with citrus, embracing four cultural and four irrigation treatments, four nitrogen levels, and four different varieties was continued (Farm 466).

An analysis of growth and yield data from the beginning of the treatments (1947) till 1954 revealed that growth and yield were affected adversely by light irrigation. Nitrogen (as ammonium sulphate) influenced growth and yield favorably only in the grass sod and bare soil untilled treatments. On the other hand, nitrogen fertilization affected the quality of the fruit adversely almost in proportion to the amount applied. This effect was more pronounced in the grass sod than in the bare soil treatment, while the two summer clean cultivated treatments were less affected. Best fruit was produced from summer clean cultivated treatment, with or without farmyard manure.

Analysis of citrus leaves sampled in January, 1954 (spring cycle), from the Farm 466 experiment indicated a possible deficiency in phosphorus, while with the higher nitrogen levels there is probably a luxury consumption of nitrogen. The figures for leaf phosphorus (phosphorus in dry matter) indicate a low phosphorus content in the trees of the grass sod. The higher the nitrogen level, the lower is the phosphorus content. Of the two summer clean cultivated treatments, the one with farmyard manure shows the higher figures for leaf phosphorus.

Soil analysis for available phosphorus confirm the suspicion of a phosphorus deficiency. Estimations of total phosphorus are at present being carried out.

These conclusions reflect conditions which are fairly general throughout the Murrumbidgee Irrigation Area, as shown by a survey of sample orchards in the district. This survey brought out a reasonable relationship between leaf and soil phosphorus on the one hand and fruit quality on the other hand.

Work is now in progress to determine more precisely the role of phosphorus and nitrogen in the nutrition of the trees and its possible effect on fruit quality. In this connexion the effect of the heavy continual use of ammonium sulphate on the trees and on the soil is also of importance. The sharp decrease in pH of the soil from just below neutral to as low as pH 4.5 in the experiment and generally in the district is one aspect of this problem. The response of citrus to either nitrate or ammonia nitrogen is being studied on citrus cuttings in a glass-house experiment.

The design of the factorial experiment on Farm 466 has been modified in such a way that half of the nitrogen treatments receive sufficient lime to bring the pH back to the neutral point.

Two farm trials are also in progress, one to test the effect of phosphorus on citrus, the other one to get more information on the effects of lime on citrus.

(*c*) *Plant Physiology.*—(i) *Plant Water Relations.*—The response of the young tomato plant to a brief period of water shortage has been assessed in some detail. It has been found that growth is impaired at a fairly early stage in the development of a water shortage. The degree of water stress in this early stage is being examined further, with the aid of controlled conditions of temperature, humidity, and light.

The ontogenetic effects of water shortage have been studied in the tomato by assessing the response of individual laminae and petioles. The work is being extended to study responses to a single moderate water shortage imposed at differing stages in growth of plants exhibiting pronounced cycles of root and shoot growth.

In the work with the tomato, chemical analyses for nitrogen, phosphorus, protein nitrogen, and nucleic acid phosphorus had shown that very little nutrient had been taken into the plant during the water shortage, but that active uptake had been resumed upon rewatering. Uptake of phosphorus was depressed more than nitrogen during wilting. Upon recovery the course of uptake of phosphorus differed from that of nitrogen. To assist in interpreting these phenomena, two levels of soil phosphorus have been included in the present work.

Several aspects of this work are being examined further in a growth experiment with citrus cuttings.

(ii) *Citrus Physiology.*—In the experiment on Farm 466, chemical analyses of leaves have been carried out as part of an investigation of leaf development in relation to irrigation and cultural treatments.

(iii) *Growth Experiment with Citrus.*—Little is known of the effects of a water deficit on tree growth. A glass-house experiment with citrus is in progress using Washington Navel cuttings rooted in sandy loam, to study the effects on growth of temporary water deficits established at differing stages in the cycle of shoot and root development.

At the same time it is hoped to gain useful information regarding the role of ammonium and nitrogen ions in the nutrition of citrus and also regarding the phosphorus nutrition of the citrus plant. Treatments have been laid down in soil and sand culture. This information should be of general value in studies of citrus quality, and in the interrelations of shoot and fruit development.

The water studies are being paralleled with studies of the effect of temporary increases of chloride ion in the nutrient medium on the growth of the citrus plant in sand culture.

The growth experiment aims at the analysis of the response of the plant as a whole and of the different organs of the plant to the treatment imposed.

(*d*) *Irrigation.*—Studies have continued on the effect of weather elements and soil moisture on the rate of moisture withdrawal from the soil. The water removed from the soil is measured by means of weighable tanks sunk into the soil. It is found that the rate of water removal is affected both by the weather and by the wetness of the soil.

Studies of the drying out of soil on a district basis during the winter have continued. It is now possible to predict fairly accurately two or three weeks in advance when irrigation water will be required. This is important in deciding when the channels should be filled to begin the irrigation season.

V. ANIMAL HEALTH AND PRODUCTION.

1. General.

The Division of Animal Health and Production is responsible, within the framework of the Organization's programme of research into problems of the animal industries, for investigations concerned with animal health and reproduction and with general animal husbandry. The importance of live-stock production to the national economy cannot be too strongly stressed and any increase in knowledge in this field ultimately affects every member of the Australian community.

The head-quarters of the Division is located in Melbourne but its activities are spread throughout the Commonwealth. Reports on the work in progress are presented in this chapter and in Chapters VII. and VIII.

The work of the Division of Biochemistry and General Nutrition on nutritional problems is reported in Chapter VI. Section 12 of this chapter deals with investigations of the Animal Genetics Section other than those on sheep and cattle which are included respectively in Chapter VII., Section 15, and Chapter VIII., Sections 8 and 9.

Division of Animal Health and Production. — The established investigational programme was followed, with certain modifications, during the year. Following upon the retirement of Dr. L. B. Bull, C.B.E., Mr. D. A. Gill has succeeded him as Chief of the Division. Dr. D. F. Stewart has replaced Mr. Gill as Officer-in-charge, McMaster Animal Health Laboratory, Sydney. Dr. T. S. Gregory has taken over as Officer-in-charge, Animal Health Research Laboratory, Melbourne, *vice* Dr. A. W. Turner, and Dr. I. W. McDonald has been appointed Officer-in-charge, Sheep Biology Laboratory, Prospect, New South Wales. Mr. I. L. Johnstone resigned as Officer-in-charge, Regional Pastoral Laboratory, Armidale, New South Wales, and Mr. J. F. Barrett is acting as Officer-in-charge.

At Prospect a new building has been constructed to house small animal colonies, surgical and other facilities, and the equipment required for studies in climate physiology. A new laboratory has been established at Rockhampton to provide facilities for research staff concerned with the problems of climatic adaptation of cattle in the tropics. The work at this laboratory will be closely integrated with that at "Belmont", the National Cattle Breeding Station. The area of the Amherley Field Station near Ipswich, Queensland, has been increased, and special cattle stall have been constructed there for use in tick resistance studies.

To relieve the Chief in some measure a Committee of Management has been set up to take over some of the heavy research and administrative duties involved in the management of such a large Division. The Committee members are the Assistant Chiefs of Division with the Divisional Secretary, under the chairmanship of the Chief. A research committee has been established to direct the work of the Regional Pastoral Laboratory at Armidale, and to ensure effective collaboration there between staffs of the University of New England and C.S.I.R.O.

Grateful acknowledgement is made of financial assistance received from the wool industry, the Australian Meat Board, the Australian Dairy Produce Board, the Commonwealth Bank, and the United Graziers' Association of Queensland.

2. Animal Health Research Laboratory, Melbourne.

(Division of Animal Health and Production.)

There have been few changes in the overall research programme. Work based on this Laboratory is concerned principally with investigations of certain infectious diseases, general and chemical pathology, and microbiological chemistry. The main investigations in progress are—

Pleuropneumonia of cattle (*see* Chapter VIII., Section 2); mastitis and infertility in dairy cattle (*see* Chapter VIII., Section 2); haematuria vesicalis of cattle (*see* Chapter VIII., Section 2); brucellosis of cattle (*see* Chapter VIII., Section 2); toxicity of large rations of wheat (*see* Chapter VII., Section 12); infertility and physiology of reproduction in sheep (*see* Chapter VII., Section 13); toxaemic jaundice of sheep (*see* Chapter VII., Section 17); sheath rot of wethers (*see* Chapter VII., Section 17.)

3. McMaster Animal Health Laboratory, Sydney.

(Division of Animal Health and Production.)

This year has been marked by the generous gift of £52,000 by the late Sir Frederick McMaster to erect a wing at the McMaster Laboratory to commemorate his son, Captain Ian McMaster, M.C., who died of wounds at El Alamein. Sir Frederick McMaster was an outstanding figure in the community and a generous benefactor who had the welfare of the country at heart. The erection of the Ian McMaster Wing will relieve the present congestion in the main building and enable the research staff to be accommodated adequately.

The major investigations undertaken at the Laboratory include studies on internal and external parasites of sheep (*see* Chapter VII., Sections 18 and 19); problems concerned with drought feeding of sheep (*see* Chapter VII., Section 11); fattening of beef cattle (*see* Chapter VIII., Section 7); biochemical studies, particularly in relation to vitamin A (*see* Chapter VII., Section 11); and the investigation of certain diseases of sheep (*see* Chapter VII., Section 17).

4. Veterinary Parasitology Laboratory, Yeerongpilly, Queensland.

(Division of Animal Health and Production.)

This laboratory was established in 1948 to undertake investigations into parasites affecting live-stock, particularly those of importance in Queensland. The laboratory also provides accommodation and facilities for officers of the Division of Entomology who are engaged in studies on the cattle tick, *Boophilus microplus*. Facilities for field work are provided by Amberley Field Station, near Ipswich.

Investigations in progress by officers of this Division include studies on: *Haemonchus contortus* of cattle and sheep (*see* Chapter VIII., Section 3); liver fluke (*see* Chapter VIII., Section 3); host reactions to tick infestation (*see* Chapter VIII., Section 4); tick toxins (*see* Chapter VIII., Section 4); parasitic gastro-enteritis of cattle (*see* Chapter VIII., Section 3); worm nodules (*see* Chapter VIII., Section 3); and protection against blowfly strike in sheep (*see* Chapter VII., Section 20).

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

(Division of Animal Health and Production.)

The sheep carried have maintained good condition during the year although fleece-rot has been widespread and blowfly strike was troublesome in the late summer. There are now 65 cattle in the dairy herd of which 54 are Zebu crossbreds.

The work with dairy cattle is reported in Chapter VIII., Section 6. Other investigations in progress are: inbred flocks of Australian Merinos (*see* Chapter VII., Section 14); inheritance of component fleece characters (*see* Chapter VII., Section 14); fleece-rot (*see* Chapter VII., Section 14); birth coat studies (*see*

Chapter VII., Section 14); studies on twins (*see* Chapter VII., Section 14); defective udder studies in ewes (*see* Chapter VII., Section 14); and coat-shedding studies on cattle (*see* Chapter VIII., Section 6).

6. Sheep Biology Laboratory, Prospect, New South Wales.

(Division of Animal Health and Production.)

The research work at this laboratory has been continued. A new building has been constructed to house the equipment required for studies in climate physiology; the building includes two rooms, each capable of housing fourteen sheep or five head of cattle, in which temperature and humidity can be accurately controlled over a wide range. Apparatus required for these rooms has been constructed by the Central Experimental Workshops (*see* Chapter XXV., Section 5). The general purpose of this development is to conduct a long-term study of the physiological mechanisms which affect the response of sheep and cattle to climatic conditions and especially to hot conditions.

The chief investigations at present in progress are: metabolism of pregnant ewes (*see* Chapter VII., Section 10); physiology of reproduction (*see* Chapter VII., Section 13); a study of the Australian Merino Flock Register (*see* Chapter VII., Section 14); endocrinology of wool growth (*see* Chapter VII., Section 16); histology of skin and hair (*see* Chapter VII., Section 16); the development of skin and fleece (*see* Chapter VII., Section 16). The work of the Merino strains trial (*see* Chapter VII., Section 14), is also centred at Prospect.

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

(Division of Animal Health and Production.)

The Regional Pastoral Laboratory at Armidale and its associated Field Station, "Chiswick", were established in 1947. At present the research team consists of Officers of the Divisions of Animal Health and Production, Plant Industry, and Mathematical Statistics, and Wildlife Survey Section.

The work of this Division at Armidale has been concerned with epidemiological and ecological aspects of parasitism, problems of fertility in ewes, and the survival of new-born lambs. The utilization and management of land units with varying proportions of sown and native pastures, and the effects of grazing management on pasture and on animal production, are also being studied. Based on a detailed ecological survey of the New England Region, the Division of Plant Industry has an extensive pasture research programme in progress. It includes plant introduction studies, studies on native pastures, problems of plant nutrition, and the development, maintenance, and utilization of sown pastures. Officers of the Wildlife Survey Section have commenced investigation of the rabbit problems of the region (*see* Chapter X., Section 2).

At "Chiswick" an area of 1,115 acres was cultivated during the year, of which 1,000 acres were sown to pastures and lucerne. Sheep shorn totalled 4,592, yielding 121 bales of wool, or an average of 8.1 lb. per head. In addition, 120 cattle and ten horses were carried. The work carried out by officers of the Division of Plant Industry is reported in Chapter III., Section 19, and by officers of the Division of Animal Health and Production in Chapter VII., Section 18. "Chiswick" is one af the centres used in the Merino strains trial and progress in this work is reported in Chapter VII., Section 14.

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

(Division of Animal Health and Production.)

In 1954, approximately 18 inches of rain were recorded. This is 5 inches greater than the yearly mean for Cunnamulla. Pastures made excellent growth following rains after fifteen dry weeks in the autumn.

Approximately 4,500 sheep and 2,000 lambs were shorn in February-March, 1955. These sheep were running on approximately 40,000 acres. The mean greasy wool weights of fifteen-sixteen-month-old ewes were: medium Peppin Merinos 10.2 lb., fine non-Peppius 9.4 lb., and strong non-Peppin 11.8 lb. Lamb-marking results (lambs present at marking as a percentage of ewes present) of different flocks varied from 77.5 to 89.3 per cent.

The work done on the station consists primarily of long-term Merino breeding trials. These trials include AB1, the strains trial, and a study of the inheritance of hornedness in sheep (*see* Chapter VII., Section 14).

9. National Cattle-Breeding Station, "Belmont", Rockhampton, Queensland.

(Division of Animal Health and Production.)

The winter of 1954 was very favourable for pasture growth and good rains were received in the early summer. Torrential rains fell in February and March, and about 1,000 acres along the Fitzroy River were inundated for six weeks. This caused little damage but forced the concentration of stock on the higher country, leading to over-grazing there. With the clearing and development of the eastern portion of the Station it will be possible to avoid this in future floods.

The experimental cattle yards have been completed and two sets of cattle-weighing scales installed. In addition, a small field laboratory has been built and a 120-ft. crush for temperature and respiration studies completed. Eight miles of new fence lines were erected and a start made on clearing scrub.

Approximately 1,100 cattle are now on "Belmont". Their health has been good although some losses occurred from lantana poisoning. The Shorthorns, as a group, have not adapted themselves to the conditions as satisfactorily as the Herefords.

A laboratory has been established in Rockhampton to co-operate with "Belmont" in studies concerned with the physiological adaptation of exotic (Zebu and Africander) and British breeds (Shorthorn and Hereford) to this environment, to study the inheritance of the characters of value in adaptation, and to determine the relationship between various attributes and the economic performance of the animals. Preliminary results of this work and a progress report on the breeding programme at "Belmont" is given in Chapter VIII., Section 8.

10. Poultry Research Centre, Werribee, Victoria.

(Division of Animal Health and Prodnction.)

Studies in population genetics and physiology of reproduction are the two main research projects at this Centre. Progress reports are given in this Chapter, Section 11.

A total number of 1,040 dams were selected during the 1954 breeding season and inseminated with semen from 105 selected cockerels and 12 two-year-old cocks. The total population of adult birds at March, 1955, was 5,756, of which 3,950 were White Leghorns, 784 Australorps, and 1,022 crossbreds of various types.

11. Investigations Other than with Sheep and Cattle.

(Division of Animal Health and Production.)

In addition to work at the main centres described in previous sections of this chapter, staff of the Division are also located in Western Australia, South Australia, Queensland, and Tasmania, working in association with Departments of Agriculture and Universities. Work is proceeding at the University of Adelaide in genetics (*see* this Section); at the University of Queensland on the effects of high temperature on pregnancy in Merino ewes, on breeding season of Merino ewes in relation to length of day (*see* Chapter VII., Section 13), and on seasonal coat changes in cattle of European origin (*see* Chapter VIII., Section 7); with the Department of Agriculture in Perth on the copper metabolism of sheep (*see* Chapter VII., Section 17) and on the comparative biochemistry of copper and on the cobalt status of pastures (*see* this Section); and with the Department of Agriculture in Tasmania on a new project at "Frodsley", to elucidate the effects of fertilizers, including potash, on the production of pastures there and on the health and growth of sheep.

(*a*) *Studies on Microbial Metabolism (Animal Health Laboratory, Melbourne).*—Fundamental studies on microbial metabolism are being made both for their intrinsic value and for the better understanding of microbial action in relation to animal nutrition and animal diseases. In addition to work on the metabolism *Asterococcus mycoides*, the casual organism of bovine contagious pleuropneumonia, metabolic investigations have been made on *Polytoma uvella*, a non-chlorophyllous phytoflagellate. A study of the pathways of acetate metabolism in this organism has included the utilization of acetate C, the contribution of acetate C to the synthesis of aspartic and glutamic acids, and the fixation of radioactive CO_2 into ethanol-soluble compounds.

(*b*) *Physiological Genetics (University of Adelaide).*—Studies on the nature and mode of action of the gene were continued with the mould *Neurospora crassa* as the experimental organism. The synthesis of stock cultures containing from ten to thirteen specific genes for studies on nuclear cytoplasm interactions and on mutation at a specific locus has been completed, and the cultures are in use.

The nature of radiation-induced gene mutations is being investigated. A study of the mechanism of the competitive suppression of the wild-type back-mutants by the large number of non-growing mutants frequently present has revealed that the non-growing mutant cells remove sugar from the medium at such a rate that insufficient is left for the back-mutant cells to grow to macroscopic colony size. Suppression can be overcome by increasing the sugar content of the medium.

Work on the genetic and environmental control of differentiation in *Neurospora* has been completed and the results prepared for publication.

(*c*) *Studies in Population Genetics (Poultry Research Centre).*—Analysis of the records of the F_6 generation of pullets at the Poultry Research Centre has indicated—

(i) The control flock of White Leghorns propagated without selection has remained at about the same level of egg production since the beginning of the experiments.

(ii) Selection for good and bad body conformation has not affected egg production in comparison with the control flock.

(iii) Selection of low-producing hens and the males of this group was also ineffective in changing production from the level of that of the control flock.

(iv) Mating of mass-selected dams with sires from high-producing dams led to increased production of eggs to the level attained by the best family-selected flock in this year.

(v) The White Leghorn flocks developed by family selection differ mainly according to the type of mating used. The flock based on selection for absence of winter pause made steady progress in egg production. The flock in which cockerels were selected on the basis of sib-testing for part-winter period and mated to their half-sib pullets increased production considerably. The pullets of the highly inbred strains reached a coefficient of inbreeding of 48 to 63 per cent. Great differences were observed between these strains which were selected for egg production and sire families within the strains. While some families died out, others showed good hatchability and vigour and a few reached a level of egg production equal to the best flocks of White Leghorns.

The crossbreeding programme has been modified. Crossbreds again outproduced pure-bred half-sibs by approximately 24 eggs per annum. The criss-cross series, now in the seventh generation, produced as many eggs as the single crosses and were superior in terms of chick mortality.

(*d*) *Physiology of Reproduction (Poultry Research Centre).*—Studies concerning the transport of fowl sperm have shown that live sperm reach the infundibulum in less than 30 minutes. The junction of the uterus and vagina acts as a limiting mechanism to the numbers of sperms reaching the infundibulum where fertilization takes place. A new technique developed to permit deposition of sperm directly into the uterus has resulted in many more sperms reaching the higher levels of the oviduct. A level of 73 per cent. fertility was attained by intra-uteral insemination with deep-frozen semen which had been suspended in a glycerol diluent and had not been dialysed, as against nil when such semen was placed in the vagina.

Semen quality tests were made throughout the breeding season. Inbreeding was found to depress the quantity and quality of semen produced.

(*e*) *Comparative Biochemistry of Copper (Department of Agriculture, Perth).*—The range of data has been increased: analyses were made of blood and liver samples from seals and penguins of the Heard Island and Antarctic regions and also from coelocanth samples obtained from Madagascar.

The blood copper level was found to be highest in the pig (1.4 mg Cu per litre whole blood) and lowest in the domestic fowl and turkey (0.23). In marsupials it was low, but in most other animals it lay between 0.5 and 1.0 mg per litre.

In most species, values for liver copper were lower than 50 p.p.m. on a dry weight basis. High values were obtained with ruminants, the duck, and the frog, and in certain fish. The development of unusually high values is the subject of further studies.

(*f*) *Micro-element Deficiency Survey Work in Western Australia.*—Fewer samples were examined than in previous years. The examination of several samples from the Manypeaks area, east of Albany, revealed an acute cobalt deficiency in this region. Following a report from plant nutrition workers, analyses showed a high molybdenum status of plants taken from a peat swamp near Rockingham, but cattle grazing in this area have shown no clinical evidence of copper deficiency.

(*g*) *High Iron Values in Tissues of Animals from the Antarctic Regions.*—Iron values were especially high in seal livers and were associated with the deposition of haemosiderin. It has also been shown that the blood of seals from Heard Island contained 22-24 g of haemoglobin per 100 ml.

12. Animal Genetics.

(Animal Genetics Section.)

The Animal Genetics Section aims to investigate the possibility of applying genetics to animal breeding and allied fields and to train students interested in the subject. One Honours student from Physics took her M.Sc. degree this year. Four students are now undertaking post-graduate training. The Section started an advanced course on experimental biology this year for Honours and post-graduate students. A teaching film demonstrating the main features of meiosis was completed in collaboration with the Film Unit.

The Section is to be housed in future in the Zoology Department of the University. A set of laboratories has been planned and building started which should enable the section to move into the Zoology building by the end of the year. A rabbit house to hold 600 rabbits has been completed at Prospect.

(*a*) *Mouse Breeding.*—The experiments in which mice are selected for sensitivity to oestrogens has gone through a further three generations. Progress continues to be rapid. The method of sequential testing proved to be accurate. Whereas in early generations, lines which were very different in sensitivity to oestrogens when tested intravaginally were identical when tested subcutaneously, in the last generation a separation has taken place between the lines in sensitivity to oestrogen given subcutaneously.

Work on tibia length has been discontinued; it proved too slow and the point under test will be tried out on *Drosophila melanogaster*. These experiments are under way.

Variability between sublines of inbred lines is to be tested to estimate the extent to which new variation occurs by mutation. Ten inbred lines have been split into five sublines each and these have now run for five generations. Differences between the sublines in several metrical characters will be tested this generation. A similar investigation is being undertaken using *D. melanogaster*. Work on the coat of genetically abnormal mice continues. It has been shown that the hair cycles in Naked mice are profoundly affected by pregnancy and lactation. Shortly after parturition all activity in the hair cycle stops. The effect can be reproduced in empty females and in entire and castrated males by injecting several of the sex hormones; oestrogen, however, is the most effective. This should help to solve some of the problems of hair shedding in cattle.

An experiment on selecting mice on the basis of a selection index has been terminated. The results are not yet analysed but surprisingly little progress was made as a result of selection for ten generations.

(*b*) *Production of Antibodies and Disease Resistance.*—The finding that response to a complex antigen has a lower heritability than response to a simple one has been confirmed using another complex antigen, sheep red cells. It is likely that the reason for low heritability lies in the technique of measuring the response, which in a mixture of antisera detects only the antiserum present in maximum amount, as has been demonstrated in using A, B, and AB human antisera and red cells. A detailed study of response of mice to sheep red cells shows that both primary and secondary responses are biphasic. This suggests either that the antigens present elicit responses which have maxima at different times or that antibody is made at sites in the mouse which have maxima at different times.

Selection of rabbits for resistance to K.M.13 myxoma virus continues. The rabbit colony can now produce 25 rabbits a week and has a potential for 50 so this work should gather momentum. To date it is clear that the resistance of the rabbits bred from recoveries has been increased slightly in so far as they take longer to kill. The experiment has proved unexpectedly difficult owing to the fact that recovered bucks, which are sterile for three or four months after recovery, never regain fertility for more than short periods which can be detected only by semen collection.

Work on variation of the myxoma virus has been postponed until a satisfactory way of growing virus outside the rabbit has been found. Attempts are being made to grow it in mouse brain. A sensitive method of assaying the virus on a single rabbit using pock size has been worked out. This was necessary in trying to adapt the virus to mouse brain in order to detect what was happening to the virus in the mouse.

(*c*) *Genes and Chromosomes.*—The analysis of nucleic acid per nucleus reported for the kangaroo last year has been repeated on the bandicoot and the possum. Results were very similar. The amount in bandicoot nuclei was a little higher than expected. Experiments on crossing over in *D. melanogaster* show that an increase in crossing over is not accompanied by a corresponding increase in coincidence. This indicates at least a two-factor control of crossing over during meiosis. Cold treatment at — 5° C. has failed to produce a noticeable increase in the mutation rate of *D. melanogaster*. Two flies hatched from eggs frozen to — 70° C. have been tested and showed no significant increase either. This augurs well for use of deep-frozen semen in commercial breeding work, though numbers tested at — 70° C. are still too few to have much significance.

VI. NUTRITION.

1. General.

The lack of exact knowledge of ruminant physiology and the basic importance of the pastoral industries to Australia's economy first prompted fundamental studies of animal nutrition within the Organization. The research in this field has been confined mainly to the nutritional biochemistry of the sheep and the influence of nutrition on wool production.

Division of Biochemistry and General Nutrition.—As wool production still holds pride of place in Australian economy, research has been confined mainly to the nutritional biochemistry of the sheep, and more especially to the nutritional factors which govern wool production. Particular attention has been given also to the capacity of pastures to provide the nutritional requirements of grazing animals. Extension of the results of these investigations to practice in the pastoral industry has resulted in spectacular economic returns. Investigation of the sheep's nutritional requirements, for example, revealed the fact that certain soils are unable to provide the minute traces of heavy metals such as cobalt and copper which are essential for the health of grazing animals, and, in turn, led to a general realization that the productivity of vast tracts of terrain is limited by deficiencies of the trace elements copper, zinc, molybdenum, &c., which may simply and inexpensively be made good by manurial dressings.

Researches into the aetiology of a nutritional malady prevalent in flocks depastured on calcareous coastal dunes proceeded in a series of logical steps to the demonstration by the Division that huge areas in southern Australia hitherto abandoned as useless for agriculture, could be converted to high-producing permanent pastures by sowing with suitable legumes and grasses and dressing with superphosphate enriched with copper and zinc. These discoveries have provided basic knowledge and a point of view which have led to similarly

dramatic developments in many other areas, both in Australia and elsewhere. The results are of very great economic significance.

Information arising from other nutritional researches has found its way more subtly into practice to greatly increase the efficiency of animal husbandry, and add very considerably to the economic returns from the grazing industry.

Some of the current investigations are described in this Chapter and further detailed references are made under Chapter III., Section 11, and Chapter VII., Sections 2-9.

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutrition.)

A summary of the series of researches which have established an understanding of the main relationships between nutrition and wool production was presented in the previous Report. At this juncture the main emphasis of this section of the investigations is on the metabolism of the sulphur-containing amino acids and on the assessment of the extent of the synthesis of methionine and cystine through the agency of the microorganisms within the rumen. It is probable that destruction of amino acids present in the fodder proceeds there also and that, under most conditions of feeding, transactions within the rumen result in a net loss rather than a gain of these amino acids.

The relationship between the overall supply of available energy to the animal and the efficiency of conversion of fodder protein to wool fleece is also being studied to illuminate further the interplay of the nutritional factors which influence wool production.

3. Studies of the Metabolic Processes of Sheep.

(Division of Biochemistry and General Nutrition.)

Knowledge of the sheep's intermediary metabolism, i.e., of the processes by which the animal's tissues deal with the substances absorbed from the fodder, is an essential pre-requisite for the understanding of nutritional disturbances which at times seriously influence the health and limit the productivity of sheep.

Ruminants derive a greater part of the energy necessary to sustain life from simple fatty acids, mainly acetic and proprionic acids that are produced by fermentation of carbohydrates within the rumen. In this respect they are distinct from other animals, and so the metabolic processes which deal with fatty acids are especially important in the overall physiological economy of the sheep. A detailed study is being made of these processes, and of the influence of certain minor elements upon them. Some of these investigations are described in Chapter VII., Sections 3-5.

4. Energy Metabolism of the Sheep.

(Division of Biochemistry and General Nutrition.)

Studies of the thermodynamics of the overall energy transactions in the sheep have been continued.

The methods of indirect calorimetry have also been used to investigate the effects that cobalt deficiency in the fodder has on the nature of the digestion products arising from fermentation within the rumen. The experiments provided unequivocal proof that the very obvious influence that cobalt concentration has on the nature of the population of microorganisms which inhabit the rumen is not reflected in the "overall digestibility" of the fodder, nor does it affect materially the nature of the end products arising from the bacterial dissimilation of the fodder within the alimentary canal. The significance and importance of this is discussed in Chapter VII., Section 4.

5. Microbiological Processes of Rumination.

(Division of Biochemistry and General Nutrition.)

Although the mixed populations of microflora and microfauna which inhabit the contents of a ruminant's paunch are known to play an essential symbiotic role, comparatively little is known of the nutritional functions served by these microorganisms other than the "digestive" action they exert on the refractory carbohydrates, cellulose, hemicellulose, &c., which comprise the major part of the animal's fodder and which are resistant to the digestive enzymes secreted into the alimentary canal. Studies are now being made of the influence that the composition of the ingesta has on the nature and activity of this mixed population of microorganisms. It has become evident that relatively small changes in the concentration of certain inorganic ions within the rumen contents will alter very materially both the overall chemical changes brought about through the agency of microorganisms in the rumen contents and the production of vitamins that takes place there. Attention is also being given to particular aspects of the changes in the nitrogenous constituents of the fodder effected by microbial activity during the passage of the ingesta through the rumen. These experiments are referred to in Chapter VII., Section 3.

6. Salt Tolerance of Sheep and Potability of Stock Waters.

(Division of Biochemistry and General Nutrition.)

The series of long-term experiments that are being carried out to determine the toxic limits of sodium chloride and of other salts present in water consumed by grazing stock were described in the previous Report. A much more accurate knowledge of the potability of saline waters than is at present available is now desirable, as means are in prospect which may render economically feasible the reduction of the salt concentration of highly saline waters to innocuous levels, and so increase the efficiency of the utilization of semi-arid pastoral areas. The experiments are referred to in more detail in Chapter VII., Section 9.

7. Stereochemistry of Carbohydrates.

(Division of Biochemistry and General Nutrition.)

Although published evidence for the formation of compounds or coordinate complexes between metallic ions and carbohydrates is extensive, the nature of the products is known in only a few cases, and useful generalizations about the conrse of the reactions and their steric requirements are not yet possible. To achieve this end the factors involved in reaction requirements are not yet possible. To achieve this end the factors involved in reactions between carbohydrates and inorganic electrolytes are being examined systematically by the ionophoresis of sugars and sugar alcohols on paper strips in dilute solutions of inorganic salts.

In the early stages of this work, investigation of ionophoretic migration of reducing sugars and of sucrose in 0.1N sodium hydroxide has illuminated knowledge of the behaviour of sugars toward ion-exchange resins. Later, the finding that particular sets of sugars do not always show the same pattern of relative movement in all electrolytes in which complex-formation takes place has indicated that these differences can be applied to the analysis of mixtures of carbohydrates by paper ionophoresis.

A comprehensive review on "The Stereochemistry of Cyclic Derivatives of Carbohydrates", commissioned by *Advances in Carbohydrate Chemistry*, has been completed, and is in the press.

This review deals mainly with the stereochemistry of the formation of cyclic acetals from carbohydrates, and provides the rationale of the work on complex formation between carbohydrates and inorganic reagents

mentioned above. Knowledge of the course of reactions between carbohydrates and metallic cations or anions is of considerable theoretical and practical importance, especially in biological chemistry.

8. Minor Element Deficiencies in Animals.

(Division of Biochemistry and General Nutrition.)

(*a*) *General.*—The wide range of studies of the functions that traces of metals serve in living cells has been discussed in previous Reports. A series of experimental studies of the effects of cobalt and copper deficiencies on sheep grazing on deficient pastures is referred to in Chapter VII. The experiments reported below, while for most part directed to this end, have been conducted mainly with laboratory animals under controlled laboratory conditions, and with sheep in pens and metabolism cages.

(*b*) *Copper Deficiency in the Rat.*—The interplay of sulphate and molybdate in the metabolism of copper has been studied further in several series of critical experiments with rats sustained at levels of copper intake ranging from those of extreme deficiency to those of considerable excess. The results confirm the conclusions from previous experiments in this series and stress further that the toxicity of molybdate is very materially accentuated when the ingestion of sulphate is increased and that this effect may be overcome by augmenting the intake of copper. Ingestion of relatively large amounts of sulphate has little or no effect on the copper metabolism of the rat; and sulphide (as Na_2S) is well tolerated by this animal. These effects are quite different in many respects from those which supervene in the sheep.

(*c*) *Copper Deficiency in the Sheep.*—Long-term experiments with sheep pen-fed on basal rations comprised essentially of wheaten chaff and wheaten gluten, which contain very little molybdenum, have further illuminated the influence of sulphate and of molybdate on the copper metabolism of ruminants. Assessed in terms of concentration of copper in the livers of experimental sheep under these steady and otherwise adequate feeding conditions, additional sulphate materially lowered the retention of copper after an initial (ten months) period of apparent lack of effect; additional molybdenum initially limited retention and subsequently had little effect; and a combination of sulphate and molybdate limited retention throughout the whole period of sixteen months, and very strikingly lessened the physiological status of the copper present in the tissues. The observed metabolic complications introduced by molybdenum confirm conclusions drawn in previous Reports An excessive intake of molybdenum tends, paradoxically, to increase the concentration of copper in the tissues but to decrease its availability for the requirements of some, but apparently not all, of the physiological functions in which copper plays an essential role. Sulphate administered *per os* to the sheep tends to complicate the absorption or the retention of copper or both, and to favour both the formation and the excretion of the copper-molybdenum complex.

The effects that molybdate, sulphate, and other ions in the blood plasma exert on the diffusibility of copper across cell membranes is being investigated. A series of papers embodying the experimental studies of copper deficiency that have been carried out in this Division during the past eight years are being prepared, and the broad conclusions which illuminate the factors that lead to copper deficiency in grazing sheep will be published in the appropriate scientific literature.

Experimental studies of sheep grazing on copper-deficient pastures are reported in Chapter VII., Section 6.

(*d*) *Zinc Deficiency in Animals.*—Evolution of chemical techniques that render possible the almost complete removal of zinc from foodstuffs as discussed in the previous Report. A series of experiments with rats on basal diets that are ostensibly free from zinc have greatly illuminated the essential role that zinc plays in the metabolism of animals. During the year Zn^{65} of high specific activity was employed to estimate the rate at which zinc is lost from the tissues of zinc-deficient and normal animals. A number of radioautographs of the tissues of rats that had been injected with Zn^{65} were made in order to localize the organs which preferentially concentrate zinc. The experiments are being continued.

9. Vitamin B_{12} and Copper Metabolism.

(Division of Biochemistry and General Nutrition.)

(*a*) *General.*—Experiments discussed in previous Reports have provided unequivocal evidence that the effects of cobalt deficiency in ruminants are in fact those of a deficiency of the cobalt-containing accessory food factor, vitamin B_{12}, which is produced by micro-organisms within the rumen in quantities adequate to meet the requirements of the animal only when the fodder contains snfficient cobalt. Further investigations of the function of cobalt and of vitamin B_{12} are outlined below, and in Chapter VII., Section 6.

(*b*) *Microbiological Estimation of Vitamin B_{12}.*—Applications of microbiological methods for the estimation of vitamin B_{12} and its analogues to the assay of tissues and of the contents of the intestinal tract and excreta have illuminated considerably the factors which influence the production and destruction of vitamin B_{12} within the tract, and its absorption and excretiou. These studies are referred to in Chapter VII., Section 6.

(*c*) *Vitamin B_{12} and Haemopoiesis.*—The anaemia associated with vitamin B_{12} deficiency in the sheep was discussed in the previous Report. A detailed study of the porphyrin metabolism in normal and vitamin B_{12}-deficient sheep has shown that as the state of deficiency progresses the free protoporphyrin in the red cells increases very materially, and recedes to a normal concentration after reinstatement of a normal vitamin B_{12} concentration within the tissues.

Electrophoresis of red cell extracts proved that coproporphyrin is present only in very minute amounts if at all in the sheep's red cells. The same improved methods applied to the red cells of patients suffering pernicious anaemia indicated that this state of virtual B_{12} deficiency has little or no effect on the concentration of free protoporphyrin in the red cells, and that there is a significant, though not spectacular, increase after vitamin B_{12} therapy. Coproporphyrin was demonstrated to be present in the human red cells in these latter circumstances.

The macrocytic anaemia of the cobalt (vitamin B_{12})-deficient sheep was found to respond dramatically to treatment with pteroyl glutamic acid, while other symptoms of the syndrome remained unaffected.

10. Plant Nutrition.

(Division of Biochemistry and General Nutrition.)

The programme of experimental studies of the mineral nutrition of plants is being continued. Having solved the broad nutritional problems which limit production of very large areas it is no longer practicable for the Division to seek out and deal with the many individual problems of husbandry imposed by small variations in soil types that will be encountered during development. To provide knowledge fundamental to the solution of these subsidiary problems, experimental investigations of the basic nutritional factors are being actively pursued under the more easily controllable conditions of the laboratory and the glass-house. These experiments are briefly referred to in Chapter III., Section 11.

11. Field Stations.

(Division of Biochemistry and General Nutrition.)

Semi-intensive studies of cobalt and vitamin B_{12} deficiencies in sheep and of the interplay of copper and molybdenum in the nutrition of ruminants have been carried out at the Division's block of pens situated at the Waite Institute.

The experiments on salt tolerance, on protein supplements for sheep, and on the effects of chronic fluorosis, which are described elsewhere in this Report, have been conducted at the Division's central field station, "Glenthorne", a property of 600 acres situated 11 miles from the main laboratories. This station now carries 1,400 strong-wooled (Anama) Merinos and a nucleus flock of fine-wooled (Havilah) Merinos. Development of this station is proceeding as labour and materials become available.

Several other field stations are situated elsewhere on terrains where deficiencies occur. Field investigations of phalaris staggers and of the deficiencies of copper and cobalt in sheep are proceeding at Brecon and at Robe respectively.

12. Phalaris Staggers.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 7.

13. Urea and Nitrogenous Compounds as a Source of Nitrogen for Rumen Microorganisms.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 8.

VII. SHEEP.

1. General.

The sheep holds a unique position in the Australian economy. Wool is our major export, and primary products from the sheep industry such as wool, lamb, mutton, and hides comprise up to 45 per cent. of all Australian rural production. The sheep, too, allows of the use of vast areas of marginal land which it has not so far been practicable to use for other purposes. With a sheep population of over 125,000,000 Australia produces about one-quarter of the world's wool and about twice as much as any other country. More than one-half of the world's production of fine wool comes from our dry inland areas. Thus, Australia has a vital interest in ensuring that wool can withstand the competition from artificial fibres. The remarkable success of the latter has been due in the main to the clear understanding, arising from research, of the physical and chemical properties of the new fibres. Moreover, the chemical industry established to produce them is planned as a co-ordinated and organized unit, which ensures maximum efficiency and minimum wastage at all stages.

It is a major aim of the Organization's integrated programme of research in aid of the wool industry to investigate every phase of sheep and wool production: soils, pastures and nutrition, genetics, animal husbandry, wool processing, textile manufacture, and the exploitation of by-products. The Organization has been given responsibility for carrying out this extensive programme under the provisions of the *Wool Use Promotion Act* 1945. The Government has set aside funds earmarked for this purpose amounting to almost £400,000 per annum in a Wool Research Trust Account. Further moneys for capital expenditure are available from interest on the £7,000,000 of the Wool Industry Fund.

Soil fertility is obviously of prime importance and outstanding results have been achieved in improving soil infertility arising from minor element deficiencies. On the plant side, too, special emphasis has been placed on pasture improvement and weed control. The work of the Organization on soils, pastures, and related matters affecting the pastoral industry is carried out by the Division of Soils and the Division of Plant Industry (*see* Chapters II. and III.).

Work on the sheep itself has been undertaken within the Division of Animal Health and Production (Chapter V.) and the Division of Biochemistry and General Nutrition (Chapter VI.). The Division of Mathematical Statistics is closely associated with the breeding investigations (*see* Section 14 of this Chapter). The Animal Genetics Section's work on sheep breeding is described in Section 15 of this Chapter.

The Organization's work in the investigation of wool processing and wool textile problems is undertaken at the Wool Textile Research Laboratories and the Division of Industrial Chemistry (*see* Chapter XVI.).

The work of the Central Experimental Workshops on the construction of controlled climate rooms at Prospect is reported in Section 22 of this chapter.

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutrition.)

The general background of these studies has been discussed in previous Reports: some of the recent findings are indicated in Chapter VI.

A critical study of the causes of the seasonal variations in the rate of wool production has shown that Merino sheep on constant rations and confined in metabolism cages under carefully controlled conditions grow wool at a steady rate. By far the greater part of the marked seasonal fluctuations in the rate of wool production by Merino sheep on pastures may thus be attributed to fluctuations in the nutritive value of the fodder, and in lesser part to the changes in the demands on the energy supply brought about by environmental temperature variations. There is little or no evidence which suggests that these changes are due to hormonal influences.

During the year further studies of the influence of metabolic rate on protein utilization have been made, and the investigations of the metabolism of sulphur-containing amino acids have been continued.

3. Microbiological Processes of Rumination.

(Division of Biochemistry and General Nutrition.)

During the year the investigations concerned with the fate of nitrogenous compounds in the complex stomachs of the sheep have been continued.

A series of experiments, in which the nitrogen-lignin ratios in the contents of the fore-stomachs and the abomasum were used as a criterion of change, indicated that during fermentation of lucerne hay within the rumen more nitrogen passes from the paunch than can be accounted for by the passage of material onwards to the omasum.

Experiments described in the previous Report were repeated with sheep fed on wheaten hay containing a smaller proportion of nitrogen. Certain differences were observed. In the earlier series the nitrogen-lignin ratios in the rumen and the omasum throughout the day were substantially the same as in the fodder: in the new series the ratios were again approximately the same in the rumen and omasum, but at five, ten, and sixteen hours after feeding they were somewhat higher than in the fodder. Sheep on a diet of wheaten hay of even lower nitrogen content were found to have a significantly higher nitrogen-lignin ratio within the rumen contents than in the fodder 24 hours after feeding. Other approaches are being made to throw further light on this phenomenon before drawing the conclusions that seem to be indicated by these experiments.

Separation of bacteria and protozoa were achieved from the rumen fluid of sheep that had been fed diets of wheaten hay chaff, wheaten straw chaff + urea and oat grain, and lucerne chaff respectively. Amino acid analyses by elution from base-exchange resins were made on hydrolysates of "whole protein" preparations from these microorganisms. The results indicated strikingly similar amino acid compositions of the proteins of the bacteria from the three sources. The composition of the protozoal protein was more variable. A feature of possible nutritional significance was the unusually high proportion of lysine in the protozoa.

4. Energy Metabolism of Sheep.

(Division of Biochemistry and General Nutrition.)

Dnring the year the calorimeter chambers have been employed almost constantly in a variety of studies of the overall energy transactions in the sheep. Very carefully controlled experiments revealed that the manifest change in the nature of the microbial population that supervenes on an abnormally low cobalt concentration within the rumen does not affect significantly the overall "digestibility" of the fodder, nor alter materially the nature of the end products arising from dissimilation of the fodder within the alimentary canal: both the overall amount of combustible energy in the products absorbed from the intestinal tract and the capacity of this combustible energy to meet the energy requirements of the animal were unaffected by changes of the cobalt concentration within the rumen from a plentiful level to one of gross deficiency.

5. Carbohydrate Metabolism of Sheep.

(Division of Biochemistry and General Nutrition.)

Some novel features of the intermediary metabolism of the sheep have been mentioned in previous reports. There is now no doubt that certain metabolic channels in the adult sheep are at least quantitatively different from those of other classes of animals. Further knowledge of these differences are essential to the understanding of metabolic diseases which affect ruminants.

Detailed studies are being made of certain aspects of the carbohydrate metabolism of adult sheep and of young lambs in which quantitative differences are apparent. The ability of the young lamb to utilize glucose is similar to that of other animals, but deteriorates rapidly after the lamb begins to graze and the products of rumination take the place of its mother's milk.

(*a*) *Diabetic Sheep and Lambs.*—Surgical procedures which ensure complete removal of the pancreas from sheep have rendered possible the use of completely diabetic sheep for the study of certain aspects of carbohydrate metabolism. After pancreatectomy, both lambs and adult sheep develop severe hyperglycaemia and ketonaemia. Although the former symptom is a constant feature and is controllable with insulin, ketonaemia is not an invariable result of total pancreatectomy in the sheep. The diabetic condition of those animals which develop ketosis is similar to the syndrome which follows injection of alloxan, but there is an important difference in the insulin sensitivity of the two types of diabetic animals; the symptoms in the depancreatized animals are much more difficult to control with insulin.

This phenomenon is being investigated further in relation to fat metabolism. There is evidence from these studies that insulin plays a part in the utilization of the lower fatty acids.

(*b*) *Toxicity of Fluoroacetate.*—The toxicity of fluoroacetate has been studied further. It is evident that sheep are particularly susceptible to this poison, and that its toxicity is markedly influenced by the nature of the fodder ingested.

(*c*) *Utilization of Glucose by Intestinal Mucosa.*—Experimental investigation of the hexokinase activity of the intestinal mucosa indicates that the ability of this tissue to phosphorylate glucose is much greater in the lamb than in the adult sheep.

6. Minor Elements in the Nutrition of Sheep.

(Division of Biochemistry and General Nutrition.)

(*a*) *Cobalt Deficiency in Ruminants.*—The series of studies of vitamin B_{12} deficiency mentioned in the previous Report have been continued. The ruminant's dependence on certain classes of the microorganisms in its paunch for the production of its vitamin B_{12} requirements, and the spectacular depression of the growth of these microorganisms that supervenes when the cobalt concentration of the rumen contents falls below a critical level has been remarked upon in the previous Report. Studies during the past year have shown that the rumen flora of sheep on experimental cobalt-deficient rations (containing < 0.03 μg. Co/g.) produce 700-800 μg. vitamin B_{12}/day when the animal is supplemented with sufficient cobalt (1 mg. Co. day administered *per os*) to maintain an optimal cobalt concentration in the rumen. Removal of the cobalt supplement leads to manifest changes in the mixed culture of micro-organisms which inhabit the rumen and, within four days, the vitamin B_{12} production falls to less than a tenth of that which prevails when the animal is receiving adequate cobalt. The vitamin produced in relative abundance in the rumen is very poorly utilized; less than 5 per cent. of that produced is absorbed.

Studies show that the sheep loses approximately 6 μg. vitamin B_{12}/day from its liver during the normal course of its metabolism. Confirmatory evidence has been obtained with experimental flocks depastured on cobalt-deficient pastnres at the Division's field station at Robe. Preliminary investigations of the amount of vitamin B_{12} in the livers and blood plasma of sheep grazing on normal pastures indicate that seasonal alterations in the pastures lead to considerable changes in the amount of vitamin B_{12} produced in the rumen, and suggest that on many normal pastures the sheep are in negative vitamin B_{12} balance during a part of each year, and thus depend upon the stores of the vitamin accumulated in their livers during more favorable periods.

These experiments have greatly clarified the understanding of cobalt deficiency of grazing sheep, and have rendered especially clear the occasional rapid precipitation of the deficiency syndrome in flocks depastured on incipiently cobalt-deficient terrain.

A series of other experiments concerned with the nutritional physiology of vitamin B_{12} and with the metabolic lesions which supervene on vitamin B_{12} deficiency will be discussed fully in appropriate publications. This work is continuing.

(*b*) *Copper Deficiency in Sheep.*—The experiments mentioned in previous Reports have been continued. The findings from some of them are summarized in Chapter VI., Section 8. The behaviour of experimental flocks on copper-deficient pastures has yielded information which can now be better understood in the light of more intensive experiments with sheep in pens.

Relatively large supplements of molybdenum (100 mg./day), administered to experimental sheep depastured at Robe, limited the copper stored in the livers of sheep dosed with copper (10 mg. Cu/day), but increased the amount of copper retained by the sheep that received no copper supplement: in each case the concentration of copper in the blood was increased. Sulphate (3.2 g. SO_4/day) superimposed for a year had no significant effect on the liver storage of copper, but during this period the marked elevation of the copper content of the blood induced by molybdenum disappeared in those animals that were supplemented with 10 mg. Cu/day.

A comprehensive experiment to study further the nervous sequelae of copper deficiency in lambs born of copper-deficient ewes has been started at Robe. In this experiment the interplay of molybdenum and sulphate on the copper metabolism of the ewe and lamb will be investigated.

7. Phalaris Staggers.

(Division of Biochemistry and General Nutrition.)

In previous Reports brief reference has been made to a fatal malady which is responsible, at times and in certain areas, for serious losses of sheep and cattle that have been confined to pastures comprised essentially of *Phalaris tuberosa,* and to the discovery that a small supplement of cobalt, administered as a drench at least once each week, will completely protect the grazing animals from the poisonous effect of the toxic principle that presumably is present in the young shoots of this important perennial pasture grass.

Further experiments have been conducted at Brecon which have proved that neither cobalt nor the cobalt-containing accessory food factor, vitamin B_{12}, affords any protection if administered parenterally. The experiments indicate that the protective action of cobalt is associated with the very considerable change in the nature of the mixed population of microorganisms within the paunch which supervenes when the cobalt concentration of the ingesta is increased from an incipiently deficient level.

Some of the experiments now in progress seek to discover a means of ensuring protection that will obviate the necessity of frequent drenching. To this end, the effect of top-dressing *Phalaris* pastures with 1 lb. of cobalt sulphate/acre was investigated at Brecon where the malady is prevalent. In February, 1953, 1 lb. of $CoSO_4$/acre was spread over an experimental, *Phalaris*-dominated pasture, and an immediately adjacent area of the same pasture was left untreated to serve as a control. The experimental flock on the treated area was completely protected in May of that year under conditions which led to 10 per cent. fatalities in the flock on the control area.

In the first year, treatment of the pasture in this way increased the cobalt concentration of the *Phalaris* over twenty-fold (0.05 to 1.3 p.p.m. Co) during July, but by November the difference was only twofold (0.04-0.09 p.p.m. Co). In the following year (1954) the cobalt concentration of the treated *Phalaris* pasture was not more than 0.04 p.p.m.—i.e. below that which would afford protection—and in March, 1955, the concentrations in the new green shoots of the *Phalaris* on both areas were below 0.01 p.p.m. Thus benefit of such cobalt dressings in this area (and, from reports, in other areas) was transitory. This means of providing extra cobalt is relatively expensive, and as its effects are short lived it is not recommended. Careful management and drenching with cobalt, however, will prevent losses from this malady.

Experiments which aim to throw further light on the malady are proceeding, and to facilitate these investigations the possibility of utilizing irrigated pastures in continuous production so as to obviate the limitations imposed by variations in the incidence of rainfall are being explored.

8. Urea and Nitrogenous Compounds as a Source of Nitrogen for Rumen Microorganisms.

(Division of Biochemistry and General Nutrition.)

The possibility that urea or similar simple nitrogenous substances might find useful application as substitutes for protein supplements for ruminants has been discussed in previous Reports.

Experiments conducted with sheep in pens have shown that when the diet contains relatively large quantities of simple carbohydrates, additional urea stimulates the proliferation of microorganisms within the rumen with the result that useful quantities of protein are formed and wool production is enhanced.

The economical feasibility of supplementing flocks in this way will depend on the efficiency of utilization of the nitrogen source. Urea proved to be toxic when fed under certain conditions as a constituent of supplementary mixtures: under other conditions it was poorly utilized.

Attempts to employ dicyandiamide instead of urea were not successful. About a third of the experimental sheep died after consuming nitrogen from this source for periods of from 2-12 weeks. The symptoms were quite different from those arising from urea-toxicity which are due primarily to the liberation of ammonia at a greater rate than can be utilized by the microorganisms. The animals that tolerated the ingestion of 10 g dicyandiamide *per diem* certainly did not benefit, and their wool production was uninfluence. Thus, the possible usefulness of dicyandiamide as a nitrogen source is precluded because it is poorly utilized by the rumen flora, and is toxic in certain circumstances.

During the year under review, preliminary experiments have been conducted to investigate the feasibility of the production of useful amounts of bacterial protein by adding urea and molasses to green fodder in the course of ensilage production. The results will be reported later.

In a further attempt to produce bacterial protein from urea, without subjecting the animals to hazard, dry standing pastures were sprayed with molasses and urea. The results of these experiments were equivocal.

9. Salt Tolerance of Sheep and Potability of Stock Waters.

(Division of Biochemistry and General Nutrition.)

A series of long-term experiments have been initiated to determine precisely the tolerance of sheep to saline waters.

The first of these experiments has proved that waters containing 2 per cent. of NaCL is toxic for sheep on dry fodder: there is, however, evidence of adaptation to this high concentration. The experimental sheep whose drinking water contained 1 and 1.5 per cent. NaCL have suffered no untoward effects during the first ten months of observation; nor has this treatment had any effect on the electrolytes in the blood plasma of these animals other than to increase the chloride concentration to levels which, though considerably higher than usual, are compatible with normal health. The observations will be continued, and the effects which supervene on the addition of other ions, $SO_4^=$, HCO_3^-, Mg^{++}, Ca^{++}, &c., that are present in most artesian waters are being observed.

The hazards of chronic fluorosis originating from the high fluoride concentration of certain artesian waters has been mentioned in previous Reports. The experimental studies of the toxicity of fluorides present in the drinking water of grazing sheep have been continued. After three years, the mottling of the enamel and signs of selective abrasion of the molars has become progressively severe in the grazing sheep confined to water containing 20 p.p.m. F. This deterioration of the teeth is now having an adverse effect on the productivity of the animals—both body weight and wool production is affected, especially during the dry grazing conditions of late summer. Reproduction has not yet suffered—the number of lambs produced by ewes in this group has not differed significantly from that produced by the control ewes. The influence that high concentrations of fluoride contained in the drinking water has on the young lambs has been discussed in the previous Report.

These experiments have indicated the limits of fluoride tolerance, and have produced the knowledge upon which may be based husbandry procedures for

avoiding the untoward effects of waters containing fluoride. Problems associated with the removal of fluoride ions from artesian waters so as to render them innocuous may now be defined with sufficient accuracy to assess the economic feasibility of dealing directly with certain bore waters which limit the usefulness of some of the pastoral country.

10. Metabolism in Pregnant Ewes.

(Division of Animal Health and Production.)

Pregnancy Toxaemia Investigations (Sheep Biology Laboratory).—In continuing the biochemical investigation of this disease, studies have been made on naturally occurring cases and on normal and fasted pregnant ewes. Attention has been focused on the levels of volatile fatty acids and ketones in the blood, the utilization and tolerance of glucose and acetate, and the variations in content of coenzyme-A in tissnes.

Contradictory keto-acid analyses on the blood of sheep affected by pregnancy toxaemia were often observed and an explanation is being sought. The accumulated evidence suggests that, both in fasting and in pregnancy toxaemia, there is interference with the oxidation of C_2 compounds via the tricarboxylic acid cycle. This does not appear to be the immediate cause of the clinical condition but it may be a major predisposing influence.

11. Drought Feeding and Related Problems.

(Division of Animal Health and Production.)

Drought feeding experiments with sheep have been continued by the staff of the McMaster Laboratory in collaboration with the New South Wales Department of Agriculture at the Veterinary Research Station, Glenfield. Financial support was again provided by the New South Wales Graziers' Association from the Burdekin Bequest Fund.

(*a*) *The Performance of Merino Ewes on Maintenance and Submaintenance Rations.*—Groups of three-year-old Merino ewes were fed for seven months on rations of oat grain only plus 1.5 per cent. finely ground limestone at levels of 4, 3, and 2 lb. starch equivalent (S.E.) per head per week at daily and weekly intervals.

The results supported earlier experiments. The sheep were maintained for months in good store condition on 4 lb. S.E. At 3 and 2 lb. S.E., mean losses in body weight during the seven months were approximately 9 and 25 lb. respectively.

Few deaths occurred in groups on the 4 and 3 lb. S.E., but at 2 lb. S.E., losses increased as the experimental period lengthened and 27 per cent. died during the seven-month period. The general performance of the daily and weekly fed groups was very similar.

The results indicated that sheep can be fed satisfactorily during a drought of several months on grain only at an even lower level than previously recommended, provided sufficient care is taken to bring them on to the rations gradually.

(*b*) *Utilization of Low-quality Roughage by Merino Sheep.*—Adult Merino wethers were fed *ad lib.* for 195 days on low-quality roughage (chaffed cereal straw and wheaten chaff) which contained 3.5 per cent. crude protein. Subgroups were given a supplement of 4 oz. per head per day at daily, twice-weekly, and weekly intervals. The supplement contained 18.9 per cent. crude protein and consisted of a mixture of lucerne chaff, wheat, linseed meal, molasses, and cobaltized salt plus vitamin A. The control group lost an average of 30.5 lb. body weight, whereas the loss in the supplemented groups ranged from 4.8 to 11.1 lb. The control group consumed an average of 0.99 lb. low-quality roughage per head per day, and the supplemented groups 1.16 to 1.60 lb. The supplemented groups also produced 1 to 1.5 lh. of wool per head more than the controls. Of the control sheep 25 per cent. died compared with 2.8 per cent. of those which received a supplement.

In a second experiment, approximately 450 two-tooth Merino ewes were divided into 22 uniform groups. The comparative performance was investigated of sheep fed *ad lib.* for 168 days on low-quality roughages which contained 2.4 and 3.5 per cent. protein (chaffed oaten straw, 2.4 per cent. protein, and appropriate addition of wheaten chaff to attain 3.5 per cent. protein). Within each of these major groups, subgroups received supplements daily or twice weekly. The supplements used (per head/per day basis) were 6.1 oz. lucerne chaff, 4 oz. mixed supplement, as used in the previous experiment, 3.14 oz. linseed meal, 3.14 oz. cracked wheat, 3.14 oz. cracked wheat plus 7 per cent. uren, and 0.038 per cent. sulphur.

The control ewes on 3.5 per cent. protein roughage survived longer and cut more wool than those on the 2.4 per cent. protein roughage. Within each experimental subgroup those on the basal 3.5 per cent. protein roughage showed higher survival rates, greater wool production, and smaller body weight losses, and consumed more than those on the 2.4 per cent. protein roughage.

Of the supplements used, linseed meal gave the best results. There was little difference between lucerne chaff, the mixed supplement, and wheat plus urea and sulphur.

(*c*) *Vitamin A Requirement of Sheep.*—The groups which received lucerne chaff or the concentrate mixture in experiments referred to under (*b*) maintained relatively normal plasma vitamin A levels throughout, whereas the other supplemented groups showed significant decreases. The vitamin A levels of the control groups showed little change throughout.

The relative efficiency, absorption, storage, and utilization of a single dose of vitamin A was studied when given to sheep in oil, as an emulsion or as a water-soluble dispersion. There was no significant difference in the performance of the three treated groups and all were superior to the control animals which were grossly depleted in vitamin A. A single massive dose satisfied the vitamin A requirements of sheep for approximately six months after treatment.

Plasma samples were collected from grazing ewes in New South Wales and Western Australia to detect changes in the vitamin A levels over prolonged dry periods, but unseasonable rains have interfered with these projects.

12. Toxicity of Large Rations of Wheat.

(Division of Animal Health and Production.)

When sheep consume excessive amounts of wheat or other cereal grains, severe haemoconcentration occurs and may reach 140 per cent. or more. Interest has mainly centred upon the mechanism of this condition.

It has now been shown that the haemoconcentration is associated with a fall in plasma volume and a great increase in red cell volume, and that there is little change in blood volume. Further experiments showed that the increased red cells were derived from the spleen, an important blood reservoir in the sheep. The change in plasma volume appears to be due, at least in part, to osmotic movement of water from the tissues into the rumen. The general picture appears to be that the rapid generation of large amounts of lactic acid in the rumen gives rise to greatly hypertonic fluid. This in turn leads to progressive osmotic hypohydraemia, during the earlier stages of which the entry into the blood of red cells stored in the spleen tends to keep the blood volume normal. Since the limit of this compensatory mechanism appears to be about 30 per cent., further haemoconcentration is probably then due to continued fall in plasma volume

and hence of blood volume. The characteristic lactacidaemia and acidosis are probably due partly to enterogenous lactic acid absorbed from the rumen or elsewhere, and partly to endogenous lactic acid arising as a consequence of stagnant hypoxia from haemoconcentration and possibly also of histotoxic hypoxia.

A toxic factor in ruminal fluid from wheat-gorged sheep, similar to that described by Dougherty in 1949, was studied. Intravenous injection of 1-10 ml. caused severe haemoconcentration within a few minutes. Injection of normal ruminal fluid was without effect. This investigation is continuing.

13. Infertility and Physiology of Reproduction.

(Division of Animal Health and Production.)

(*a*) *Breeding Season of Merino Ewes in Relation to the Light Environment* (*University of Queensland*).—To test the response of Merinos to the light environment, two groups of Peppin strain ewes with vasectomized rams have been observed for incidence of oestrus.

The control group received the daily duration of lighting normal for Brisbane. The second group was subjected to reverse seasonal lighting conditions by means of appropriate black-out arrangements and supplementary artificial lighting. The experiment began in February and oestrus was at a high level in both groups during the first three months. Thereafter the effect of the light treatment became apparent and, after May, the trend in the incidence of oestrus was opposite in the two groups. The results indicate that the oestrus pattern in Merinos resembles that of the mutton breeds, but is less decisively separated into seasons of quiescence and activity, and that the breeding season is regulated by light change.

(*b*) *Seasonal Variation in the Level of Fertility in Merino Sheep* (*Animal Health Laboratory, Melbourne*).—Observations to compare the results of joining in June-July and December-January have been completed. Fewer lambs were born following the June-July joining owing to the failure of some ewes to mate, the failure of others to lamb, and the occurrence of somewhat fewer twin pregnancies. The results of joining in mid-December were very similar to those obtained in previous years.

Merino ewes, six to seven years old, selected for a high proportion of twin births, were brought into pens and maintained at constant weight on a uniform diet of dry feed. The ovaries were examined on four occasions by laparotomy, and significant variation was found in the proportion of ovulations which were multiple. These observations are proceeding.

(*c*) *Failure in Conception and Embryonic Mortality in Merino Ewes.*—Of 67 ewes, 34 were found to have more than one corpus luteum in the ovaries, and the number of foetuses in the uterus 93 to 136 days after mating closely approximated the number to be expected if each ovum, whether occurring singly or otherwise, were to have an equal chance of giving rise to a well-developed foetus.

(*d*) *Induction of Heat in Spayed Merino Ewes with Stilboestrol.*—To determine the response of Merino ewes to repeated administration of oestrogen, stilboestrol is being injected into spayed ewes at fortnightly intervals. This work is in progress.

(*e*) *Diagnosis of Pregnancy in the Ewe.*—The value for experimental purposes of a type of peritonescope which is introduced through the vaginal wall is being tested. Present results suggest that pregnancy can be diagnosed with a high degree of accuracy eight to nine weeks after conception.

(*f*) *Mating and its Outcome in the Field.*—In five Merino flocks observations initiated in the previous year were continued. Failure of ewes to mate, failure to lamb after mating, and losses among lambs contributed to wastage. The relative importance of these factors varied in the sample groups from the different flocks. Failure to lamb, whether or not it was associated with failure to mate, was a more important source of wastage among the ewes joined in early November than among those joined at other times. A much greater variation, due largely to seasonal variations in the pasture, was evident in the growth of the lambs after weaning than before it.

Observations on mating and lambing in sample groups from a Corriedale flock in which half of the ewes were joined in December and half in May showed that approximately the same numbers mated and lambed, but some 38 per cent. of lambs from ewes joined in December died before marking and only 12 per cent. of those from the ewes joined in May.

(*g*) *Effects of High Temperature on Pregnancy in Merino Ewes* (*University of Queensland*).—Previous work has shown that high temperatures are inimical to satisfactory gestation in Romney Marsh ewes. Observations have now been extended to Merinos which are frequently exposed to high temperatures following spring matings in Queensland. Exposure in the hot-room for seven hours daily at 105° F. dry bulb, 92° F. wet bulb raised rectal temperatures of Merino ewes by some 3° F. and the respiration rate to about 200 per minute, but conception, lambing, and the birth weight of lambs was not affected, compared with controls, when treatment commenced on the day of mating or when the ewes were 38 days pregnant. Groups of ten and twelve ewes were used. Pregnancies in all groups were of normal duration. It was concluded that the heat treatment used, which seriously reduced lambing percentage and the birth weight of lambs of Romney Marsh ewes, was without appreciable effect on Peppin strain Merino ewes.

(*h*) *Photoperiodicity Studies on Pregnant Ewes.*—Various workers have shown that a gradually decreasing amount of light or a low light to high darkness ratio initiated oestrus and ovulation, whereas the reverse treatment inhibited their occurrence. At Armidale no differences were detected in respect to length of gestation, mortality, vigour or birth weight of lambs, increase of lamb's weight after birth, maternal instinct, or lactation between groups of twenty fine-wool Merino ewes subjected to six hours' light—eighteen hours' darkness, or 18 hours' light—six hours' darkness, and control groups kept in open pens or paddocks.

(*i*) *Physiology of the Foetal and Neo-Natal Lamb* (*Sheep Biology Laboratory*).—Previous studies on the reproduction in the sheep have indicated a need for information on the physiology of the lamb, especially during the critical periods immediately preceding and succeeding birth. The initial work has been largely exploratory in nature.

(i) *Estimation of Placental Blood Volume.*—The conventional dye dilution method for estimation of circulating blood volume proved unreliable when applied to the placenta *in vivo*. A procedure based upon injection of sheep red cells which have previously been labelled with radioactive phosphorus (^{32}P) is under investigation. Loss of ^{32}P from cells labelled *in vivo* is less rapid than from cells labelled *in vitro*.

(ii) *Relationship between Weight of Lamb and of Cotyledons.*—Correlation coefficients of about 0.7 between the birth weight of lambs and weight of foetal cotylendonary tissue of afterbirth have been found in the offspring of a heterogeneous series of ewes and in three even lines of ewes.

(iii) *Effects of Fasting on New-born Lambs.*—Lambs which were fed normally during the first 36 hours of life showed increase in weight of some visceral organs, maintained a rectal temperature above 102° F., and maintained blood sugar levels at about 110 mg./100 ml. By contrast, fasted lambs showed loss in weight

of liver and kidney fat, decrease in rectal temperature, and a fall in blood sugar level to an average of 50 mg./100 ml.

(*j*) *Effects of Malnutrition During Terminal Stage of Pregnancy in Ewes.*—Severe reduction in food intake during the last two weeks of pregnancy resulted in early parturition, reduced birth weigh of lambs, delayed onset of lactation, and reduced milk yield.

(*k*) *Rectal Temperature in New-born Lambs (Animal Health Research Laboratory, Melbourne).*—At the Tooradin Field Station the rectal temperature varied between 103 and 105° F. in most lambs during the first week after birth. In a few lambs it fell below 102° F.; in most of these the dam's milk supply was less than normal; however, it was clear that other factors may be involved.

(*l*) *Seasonal Variation in Lactation.*—A further study has been made of the milk ejection produced by different doses of posterior pituitary extract. The influence of the test interval on estimates of milk yield has also been investigated; also the completeness of extraction of milk by hand after injection of posterior pituitary extract has been compared with that when the lamb is allowed to suck. It has become evident that both strains and breeds differ in their response to posterior pituitary extract. These observations on factors which may influence estimates of milk yield are being continued, but it is already clear that, in Merino ewes, hand milking following administration of posterior pituitary extract gives a reliable estimate.

A difference in the course of lactation was found in sample lots of ewes joined in June-July and December-January respectively. This reflected a difference in nutrition due to seasonal changes in the pasture. With the lambs of the one group, born in the spring, the rate of gain to twelve weeks was positively correlated with the milk yield, but with those of the other group it was not.

(*m*) *Neo-natal Mortality in Lambs.*—(i) *Effect of Husbandry Practices on Lamb Mortality.*—Observations on the incidence of lamb deaths between birth and marking under different system of lambing husbandry were continued at Armidale in 1954. The systems compared were modified paddock lambing, station paddock lambing, unattended paddock lambing, and later lambing "off shears" and "in wool". Details of these methods were given in reports for 1953 and 1954.

(ii) *Effect of Pre-lambing Drenches of Copper Sulphate on Lamb Mortality.*—In many instances liver sections from lambs that have died within a day or so of birth show heavy deposits of haemosiderin. It was suggested that this might be due to copper deficiency in the ewes and be a possible cause of early deaths among lambs. Therefore 60 pregnant two-year-old Merino ewes were given a weekly drench of copper sulphate (70 mg. copper) for five weeks prior to lambing, but no reduction in lamb mortality resulted, compared with a similar control group. Liver copper values of three lambs in each group killed at 48-57 hr. of age were within the normal range. No haemosiderin was seen in liver sections from the three lambs in the treated group, but it was present in two out of three lambs in the control group. This will be checked in a larger experiment. However, haemosiderin has been observed in liver sections from the majority of 47 apparently normal lambs killed at "Chiswick" at intervals from birth to 48 hr. old.

(*n*) *Effect of Age at First Lambing on the Subsequent Performance of Ewes.*—In a trial commenced in 1954, fine-wool Merino ewes were mated for the first time at 7, 19, and 31 months of age to investigate the effects of age at first lambing on their subsequent performance during normal breeding life. Only three of the 40 ewes mated at seven months subsequently lambed. Of twenty ewes mated at nineteen months, eighteen lambed; and in a similar number mated at 31 months, seventeen lambed. The birth weights of the lambs from the two younger groups of ewes were lower than from the older group.

14. Breeding and Genetical Studies.

(Division of Animal Health and Production and Division of Mathematical Statistics.)

(*a*) *Inbred Flock of Merinos (F. D. McMaster Field Station).*—The programme of inbreeding without selection is continuing. In spite of the replacement of low-fertility sires, lambing results are still poor.

Matings have been discontinued in the top-crossing experiment. Final observations on the 1953 progeny will be made at shearing.

(*b*) *Inheritance of Component Fleece Characters.*—Preliminary data on density of fibre populations (parental and F_1 generations) and on ratios of primary to secondary follicles (F_2 generations) from Merino x Border Leicester crosses did not suggest dominance as far as density was concerned nor was there simple segregation in the ratios. The first progeny of the reciprocal matings were born in October.

(*c*) *Birth Coat and Follicle Studies.*—Birth coat and skin samples were taken from Merino lambs. The ratio of primary to secondary follicles at birth was 1 : 3.02 for Merinos. The high density of fibres in adult Merinos is, therefore, a post-natal development.

(*d*) *Studies on Twins in Merinos.*—(i) *Selection for Twins.*—In the first lambing of this trial 48 twin-bearing ewes mated to rams born as twins gave 24 sets of twins, whereas 53 single-bearing ewes mated to rams born as singles gave six sets of twins.

(ii) *Skin Follicle Comparisons between Twin and Single Lambs.*—Foetuses were obtained at ages of 75, 115, and 135 days and skin biopsy specimens were also taken from 20 twin and 20 single lambs at birth. Sections have been prepared for follicle counting. This study has now been extended to twin and single lambs at twelve months of age. Counting has been completed on sections taken from these lambs at birth and is proceeding on material from the same animals at twelve months of age. No differences have been found between twin and single lambs in ratios of primary to secondary follicles at birth.

(*e*) *Studies on Merino Ewes with Defective Udders.*—The results obtained have been analysed and prepared for publication.

(*f*) *Fleece-rot.*—To extend earlier observations on this problem a number of sheep from the strains trial and groups of early and late-shorn fine-wool ewes were examined at Armidale to note the incidence of fleece-rot following heavy rains over eight wet days there in January. The strong-wooled non-Peppin strain proved very susceptible, the fine non-Peppin was least affected, and the medium-wooled types were intermediate. Early-shorn (September) ewes were more seriously affected (36 per cent.) than November-shorn ewes (15 per cent.).

(*g*) *Hornedness in Sheep ("Gilruth Plains", Cunnamulla).*—Matings are being continued to test the hypothesis that there are two main pairs of genes concerned with hornedness and polledness in the Merino.

(*h*) *Statistical Study of the Australian Stud Merino Flock Register (Sheep Biology Laboratory).*—Flock records published for the period 1921 to 1950 have been tabulated and collated, and movements of breeding stock between stud flocks have been analysed. These studies have been prepared for publication.

(*i*) *Strains of Merino Sheep in Several Environments.*—In this experiment, now in its sixth year, sheep of five Merino strains are being run as small breeding flocks in each of three environments with the objection of estimating (1) the importance of strain

x environment interactions as determinants of adaptation to environment, and (2) genetic parameters for a range of strains and environments. The routine collection of data at the three field stations has proceeded and in addition, skin samples have been taken from the bulk of the ewes in the experiment to complete the description of the strains and to estimate the heritability of follicle group characteristics and their relationship to direct measures of production.

Analyses of data, so far, have aimed mainly at estimating strain x environment interactions. During the past year some of the data from animals born during the experiment have been analysed; preliminary results suggest that a similar situation to that found in the foundation ewes may obtain, i.e., that interactions between strain and location in many characters are real though usually smaller in size than the main effects.

Analyses of the relationship of crimp and fibre diameter have been continued and suggest that (1) the slope of the regression of diameter on crimp in any one strain is independent of age and location; (2) the diameter corresponding to a given crimp may be effected by both environment and age; and (3) there are considerable differences between strains in the size of this regression coefficient.

The relationship of various measured and scored wool traits to prices paid is being studied with wool data from the experiment and mean price data supplied by the Australian Wool Bureau Statistical Service. The results indicate that count is the major determinant of price with colour and length filling smaller roles.

As the various levels of production achieved by the strains may be due, in part, to differences in fodder consumption, methods of estimating the feed intake by the grazing animal are being examined.

(*j*) *Project AB*1 (*"Gilruth Plains", Cunnamulla*).—This breeding trial, conducted by officers of the Divisions of Mathematical Statistics and Animal Health and Production, was reorganized in 1954 and now consists of two parts. One part contains three closed groups with different methods of sire selection (mass, half-sib, and random control). In these groups the 1954 sires were remated or replaced by better half-sibs in 1955; control group sires were entirely replaced. The other part contains eight pairs of groups, in each of which selection is for a high or low value of a single character. In the five pairs established in 1954 unrelated rams replaced the initial sires at the 1955 matings, so as to increase the initial gene pool, but the groups will now be closed. In the other three pairs, the sires were remated or replaced by more extreme half-sibs.

Various production estimates available from AB1 and other sources have been used to calculate the age structure of ewe breeding flocks which will give the maximum return from selection. These studies are being extended to cover the optimum rate of ram turnover.

The possible effect on other measured characters of confining ewe selection entirely to greasy wool weight has been investigated theoretically, using AB1 figures. Fibre number and staple length would have been increased among the selected ewes, but the effect on other characters would have been negligible.

15. Genetics of Sheep.

(Animal Genetics Section.)

Examination of differences between breeds of sheep has continued. The fact has been confirmed that differences in fleeces between breeds does not show until the development of secondaries in the first weeks of life. An examination of Merino twins and singles also confirms earlier findings that growth rate before and after birth affects the structure of the follicle population. Slow growth results in fewer secondary follicles forming. Analysis of a wide variety of data has suggested that the weight of wool per unit area of skin is determined either independently of density of fibres or is negatively correlated with it. To get further information on this point a search has been made for mozaic sheep having patches of skin of different density. Several have been located. Two are now to hand of which one has been examined. In this the weight of wool was increased in the area where density decreased. Area of fibre per unit area of skin was the same in both types of skin, but the less dense patch grew the longer fibres.

16. Biological Studies of Skin and Wool Growth.

(Division of Animal Health and Production.)

(*a*) *Endocrinology of Wool Growth (Sheep Biology Laboratory).*—(i) *Wool Growth and the Anterior Pituitary Gland.*—Earlier experiments have shown that normal wool growth is dependent on the secretion of the anterior pituitary gland. Work is continuing to find the anterior pituitary hormones responsible. Anterior pituitary extracts are being prepared by fractional extraction at low temperatures with ethanol-water mixtures accompanied by appropriate adjustment of pH and ionic strength. Further fractionation of extracts is being carried out by continuous-zone electrophoresis. After electrophoretic analysis extracts are tested for their capacity to restore wool growth in the hypophysectomized sheep and are assayed biologically for content of known pituitary hormones.

Work is also being done on the improvement of apparatus and methods for the zone electrophoresis and chromatography of pituitary proteins.

(ii) *Wool Follicle Development and the Thyroid Gland.*—Following earlier experiments which showed that thyroidectomy of the new-born lamb suppressed the completion of wool follicle development, further work has shown that thyroxine given to ewes during pregnancy and to lambs after birth hastens the completion of secondary follicle development, but under good nutritional conditions the number of active follicles eventually produced was no greater in the treated lambs.

(iii) *Wool Growth and the Thyroid Gland.*—It has been shown that removal of the thyroid in adult sheep depresses wool growth to about 40-50 per cent. of normal. The wool growth responses of normal adult ewes to increasing doses of thyroxine have also been studied. The doses ranged from about the estimated normal secretion rate of thyroxine to sixteen times this amount. On the highest doses most of the sheep died from hyperthyroidism within eight weeks. Wool growth showed a progressive increase with increasing thyroxine dose, being about 40 per cent. greater on the highest dose. However, at doses within the physiological range which did not cause a marked hyperthyroidism, the wool growth increase was small and was accounted for by the slight increase in food intake which occurred; there was no increase in the efficiency of wool growth. The results so far do not suggest that variations in thyroxine secretion account for individual and environmental variations in wool growth.

The present results do not support the commercial use of thyroxine to increase wool growth. Further work is required to determine an acceptable degree of hyperthyroidism with regard to life-time productivity and reproductive performance before the economics of the practice can be established. Heat tolerance would be impaired in animals receiving thyroxine and higher doses would probably be tolerated better during the cooler part of the year.

(iv) *Wool Growth and the Adrenal Cortex.*—The influence of the interior pituitary on wool growth through its effect on adrenal cortical secretion is being examined. Early results support the hypothesis that the adrenal cortex exerts an inhibiting effect on wool growth, and this mechanism may underlie the condition of "break" or "tenderness" of the fleece and possibly other natural variations in wool growth rate. The administration of adrenocorticotrophic hormone to normal sheep suppresses wool growth and in suitable dosage causes "break" or "tenderness". The effects of adrenalectomy on wool growth are being examined.

(*b*) *Experimental Histology of Skin and Hair.*—The study of the development of skin in the foetus and young animal has been continued along several lines. A large part of the work has been performed on sheep but comparative aspects have been approached by experiments with mice and marsupials; colonies of two marsupial species, the brush possum (*Trichosurus vulpecula*) and the bandicoot (*Perameles nasuta*), have been established because they are extremely suitable animals for studying many of the problems of skin biology.

It has previously been observed that on the mid-side region of the foetal lamb the first primary wool follicles appear at about the fifty-eighth day of age. Skin removed from the mid-side region of a 70-day-old foetus was maintained in tissue culture for as long as 38 days. During this period, primary follicles underwent complete differentiation from simple buds to fully developed follicles with emerging wool fibres; sebaceous glands and sudoriferous glands were formed in association with primary follicles. Some follicle differentiation and wool fibre growth occurred also in cultures of skin from foetuses of 80, 98, and 124 days of age.

The histological development of the skin and wool follicles in the Merino foetus has been reinvestigated and several important processes, including the development of branching secondary follicles, were described for the first time.

The influence of the genes "Tabby" and "crinkled" on the development of hair follicles in the mouse has been studied. These genes completely alter the character of the mouse pelage by suppressing the initiation of certain hair follicles in embryonic life, and the analysis of their effects contributes to the understanding of mammalian coat development.

(*c*) *Skin and Fleece Development.*—(i) Recent evidence indicates that, in sheep under normal management, all follicles are initiated prior to birth and that, at birth, it is possible to forecast the maximum secondary-primary fibre ratio likely to be attained in post-natal life. The proportion of immature follicles which finally progress to the point of fibre production is determined by environmental conditions during pre- and post-natal life. Adverse conditions during early post-natal life limit the number of secondary follicles which mature and finally produce fibres. Pre-natal conditions appear to have only a small (but significant) effect on the numbers of follicles initiated but may well have a marked effect on the "viability" of the immature follicles present at birth.

It has been established that the great bulk (65-85 per cent.) of secondary follicles are producing fibres by the time an animal is one month of age.

Preliminary observations indicate that the number of primary follicles present on an animal is determined primarily by the size of the foetus at 90 days. Variations in density of primary follicles at this age are probably unimportant.

(ii) Investigations of the inheritance of birth-coat type in a flock of South Australian (Bungaree) strain of Merino sheep indicated very high heritability. The actual estimate of heritability from both full-sib correlations and parent-offspring regressions was 0.75. There was a small but significant difference between the mean birth-coat grade of male and female lambs—ewe lambs tended to have coarser birth coats than ram lambs. Current evidence indicates that the character is determined by a number of genes.

An association between birth-coat grade and fertility has been observed. Fine birth-coat ewes tend to have lower general fertility: this appears to be associated with a pre-natal loss of more female than male foetuses.

Investigations of the relationship of birth-coat grade to adult fleece characters are continuing.

(iii) Examination of the relationship of fleece weight to body weight in South Australian strain Merino sheep indicates that the effect of body weight is simply that of providing a greater fleece-bearing surface. No correlation between body weight and wool production per unit area of skin was observed. Studies relating to wool production from defined areas of skin are continuing.

(iv) Investigations on the effect of the plane of nutrition during pre-natal and early post-natal life indicate that adverse nutritional conditions during these stages limit the number of secondary follicles coming to maturity. If, however, adequate nutrition is subsequently permitted, little effect on body weight or total fleece production is observed. Those animals with low follicle numbers tend to produce longer and thicker fibres. These observations, together with others, suggest that the number of follicles is not a determinant of total wool production, but is a determinant of mean fibre weight. These observations are now being subjected to more detailed examination.

17. Sheep Diseases.

(Division of Animal Health and Production.)

(*a*) *"Toxaemic Jaundice" of Sheep.*—This co-operative investigation has been continued at the Animal Health Research Laboratory, Melbourne. Investigation of natural outbreaks, in co-operation with the veterinary research staff of the Department of Agriculture of New South Wales, has been carried out on the same lines as in previous years. Some of the losses investigated have been due to uncomplicated chronic copper poisoning in grazing sheep, some to straightforward heliotrope poisoning, but some have added further weight of evidence that sheep that have grazed heliotrope have become more susceptible to chronic copper poisoning and that the deaths have been due to a terminal haemolytic crisis.

Investigations of the two diseases have progressed along the following lines:—

(i) *Chronic Copper Poisoning.*—The field experiment at Tumbarumba was discontinued, but plot trials were laid down to determine the effects of dressings of molybdate, phosphate, and gypsum on the molybdenum and sulphate content of subterranean clover growing in that environment under conditions of early autumn rains. Although the season opened well there was no follow-up rain during the autumn and the observations had to be abandoned.

Further laboratory studies to determine the quantitative relationship between molybdenum and sulphate intake in their effect on copper metabolism have confirmed the earlier observations that, as the sulphate intake is raised, molybdenum becomes more effective in restricting copper accumulation in the liver of sheep on a high copper intake but that increase of sulphate intake above an optimum value has no greater effect; that for any given sulphate intake restrictions of copper accumulation in the liver and in the animal as a whole increases as the molybdenum intake increases until a maximal effect is obtained. Further increase in molybdenum intake then has no greater effect on limiting copper storage. Similar relationships between

molybdenum and sulphate intake and the rate of loss of stored copper in sheep on low copper intakes have also been demonstrated. However, when the molybdenum and sulphate intakes are raised to very high levels (100 mg. and 10 g./day respectively) loss of stored copper ceases. These conditions are accompanied by a rise in blood copper and an inhibition of copper utilization with the immediate appearance of some of the signs of copper deficiency.

Loss of fleece character, e.g., crimp, under these conditions has now been demonstrated in both Merino and crossbred sheep. There is some evidence that similar results may be brought about by appreciably lower molybdenum intakes if continued over a long period.

(ii) *Heliotrope Poisoning.*—Studies with rats of the acute and chronic toxicological and pathological effects of the pure alkaloids isolated from *Heliotropium europaeum* are continuing and a start has been made on the investigation of the effects of the administration of these alkaloids to small animals on the enzyme systems of the liver. The most characteristic change has been found to be a progressive enlargement of the liver cells which may increase twenty-fold in volume. The cell seems to lose its capacity to divide. The death rate of the cells is thus increased and the liver becomes atrophic. Further, the copper content of the liver is increased. The changes are thus similar to those which occur in sheep that have consumed *Heliotropium europaeum.*

(*b*) *Copper Metabolism Studies on Sheep in Western Australia.*—At Merredin a slight fall in liver copper values was noted after green feed became available in the autumn; this was much less than in 1951 and 1953. In the Wiluna area, where hypercuprosis occurs, histological examination of liver sections taken from apparently healthy sheep slaughtered for meat supplies failed to show any significant abnormalities. At the Bramley Research Station, sheep and also calves are being grouped for the study of the effects of grazing on a copper-deficient area. In relation to copper metabolism studies in sheep, a survey of the inorganic sulphate levels in Western Australian pastures has been commenced; so far, the samples from the agricultural areas have yielded normal to low values.

(*c*) *Sheath Rot in Sheep (Animal Health Laboratory, Melbourne).*—During the year some further observations were made on causal factors and control measures. It was reported previously that wethers affected while grazing on certain pastures usually recover if kept on a diet of oaten chaff.

Of 26 penned Border Leicester wethers, fed on equal parts of lucerne hay and oaten hay, eighteen developed the disease. Eleven of them which were moved to a bare yard and fed on meadow hay recovered within four weeks. At the Werribee Field Station 30 of 36 Merino wethers grazing on perennial ryegrass-cocksfoot-clover pastures developed lesions of all degrees of severity. The 30 affected sheep were placed in bare yards and fed on meadow hay derived from the same pastures. Twenty recovered within four weeks but even after sixteen weeks four were still affected.

It has been concluded that lucerne as hay was a causal factor, at least for Border Leicesters, and furthermore, that meadow hay made from the pasture which caused the disease when green, is virtually harmless.

(*d*) *Mycotic Dermatitis (McMaster Laboratory).*—The sensitivity of the causal organism *Nocardia dermatonomus* was tested *in vitro* to penicillin, chloromycetin, aureomycin, streptomycin, sulphamezathine, and the fungicide actadione. It proved very sensitive to penicillin, aureomycin, and chloromycetin, moderately sensitive to streptomycin and sulphamezathine, and insensitive to actadione. Some improvement resulted when seriously affected sheep in the field were treated with 1 g. chloromycetin or 600,000 units of procaine penicillin injected intramuscularly, but the cases relapsed after heavy rain. Laboratory tests are in progress regarding the most efficient route for the administration of these antibiotics to sheep.

An antigen was developed which, in a complement fixation test, detected circulating antibodies to this infection. Efforts are being made to isolate the antigenic fraction and to test its immunological significance.

(*e*) *Contagious Ophthalmia (McMaster Laboratory).* The value of 1 and 3 per cent. chloromycetin, and 3 per cent. aureomycin eye ointments, together with 1 per cent. chloromycetin in glycerine, has been tested for the treatment of contagious ophthalmia (pink-eye) in sheep. No treatment produced spectacular results, but the best were achieved with 1 per cent. chloromycetin in glycerine, particularly when the sheep were kept in the shade.

(*f*) *Footrot (McMaster Laboratory).*—An attempt was made to investigate whether *Fusiformis nodosus* could be transmitted to sites in experimental animals other than the foot of the sheep. Intradermal inoculations and scarification of the feet of rabbits and guinea-pigs, and inoculations into the anterior chamber of the eye of rabbits and sheep, were unsuccessful. The addition of clippings from the hoof of a sheep to a cooked-meat medium greatly increased the rapidity and amount of growth of *F. nodosus.* A similar effect was produced by incorporating horn clippings into a solid medium. Gelatine did not have this effect, nor did the addition of tryptophane and methionine. The addition of potato starch to the medium produced slight improvement in growth, but charcoal produced an effect equivalent to the horn clippings. The effect therefore appears to be adsorptive. No antigenic difference could be demonstrated by an agglutination tests of antisera prepared in rabbits between strains of *F. nodosus* grown with and without horn clippings.

(*g*) *Brucellosis in Sheep (Animal Health Laboratory, Melbourne).*—Limited studies on the causal organism have been continued. Although it resembles bacteria of the genus *Haemophilus* in many respects, including some growth requirements, it is considered that it more truly belongs to the genus *Brucella,* resembling a non-smooth variant of *Br. abortus.* It is of very low virulence as judged by guinea-pig inoculation tests as well as by its effects on sheep.

18. Internal Parasites.

(Division of Animal Health and Production.)

(*a*) *Studies on Anthelmintics (McMaster Laboratory).*—(i) *Phenothiazine.*—Preliminary observations suggest that pure phenothiazine may be slightly more efficient than "commercial" phenothiazine against *Trichostrongylus* spp., and that certain impurities may reduce efficiency.

For some experiments it is desirable to raise and maintain sheep worm-free on pastures. To ascertain whether repeated doses of phenothiazine would achieve this, groups of sheep in the field were dosed with either 10 g. weekly or 5 g. twice weekly for nine weeks. After the first week most faecal cultures were negative for larvae of *H. contortus* and *Oe. columbianum,* but continued to yield a few *Trichostrongylus* spp. larvae throughout. Neither method made the faeces "helminthologically sterile" and when administration was discontinued, numerous larvae reappeared in cultures within a few weeks.

(ii) *Phenothiazine Derivatives.*—The synthesis of 3:7-dichlorophenothiazine and 3:8-dichlorophenothiazine was undertaken to provide compounds for a study of the mode of action of phenothiazine. The synthetic method finally chosen involved starting from the appropriate chlorinated *o*-aminobenzene thiols.

The only general synthesis of the latter class of compound is the reaction of a substituted aniline with sulphuryl chloride to give aralthiazathionium salts and alkaline hydrolysis of these. Preparation of substantial quantities of the benzenethiols by this route required a thorough re-examination of this reaction.

(iii) *Piperazine.*—This has been shown overseas to have useful anthelmintic effects against certain nematode parasites of man, horses, fowls, pigs, and dogs, and was found very effective against *Syphacia* and *Aspicularis* species in mice. Some preliminary trials on sheep had the following results. Four g. piperazine hydrate, piperazine diacetate, or "Safersan" piperazine-1-carbodithioic betaine) injected into the rumen were uniformly 100 per cent. efficient against *Oesophagostomum columbianum* and *Oe. venulosum,* but were not effective against *Haemonchus contortus* or *Trichostrongylus* spp.; 4 g. piperazine hydrate into the rumen was not effective against *Chabertia ovina;* up to 25 g. piperazine hydrate into the rumen, or up to 10 g. into the abomasum, were not effective against *Trichostrongylus colubriformis;* 4 g. piperazine hydrate into the abomasum was not effective against *H. contortus* but a similar dose of "Safersan" (which breaks down into piperazine and carbon bisulphide in contact with gastric juice) was effective against *H. contortus* but not against *T. colubriformis;* piperazine hydrate added to a copper sulphate-nicotine sulphate mixture was very effective against *H. contortus* and *Oe. columbianum,* but the treated sheep showed severe temporary incoordination; an emulsion containing carbon tetrachloride and piperazine hydrate was highly effective against *H. contortus* and *Oe. columbianum:* morpholine acetate, related to piperazine, was ineffective against oxyurids in mice, and in limited trials with sheep was not effective against *H. contortus* or *T. colubriformis.*

(iv) *Miscellaneous Anthelmintics.*—Further trials with hexachlorethane in solution in liquid paraffin or tetrachlorethylene, or in mixtures of these, showed that 4 g. was effective against *H. contortus* and *Fasciola hepatica* when injected into the rumen, whereas the usually recommended dose of hexachlorethane, as a dispersible powder, is 15-20 g. per sheep.

Nicotine sulphate (0.75 ml. in 30 ml. water) given to sheep after swabbing the mouth with 10 per cent. copper sulphate to close the oesophageal groove, was effective against *T. axei,* but 1.2 ml. injected into either the rumen or the abomasum was not effective against *Moniezia* spp. These results are contrary to the usual recommendation that nicotine is effective against tapeworms in sheep.

A dose of 0.125 g. sodium arsenite into the rumen was not effective against *Moniezia* spp., but the same dose into the abomasum was effective. It appears that, if soluble arsenicals are used against *Moniezia* spp., they should be administered with or immediately after a dose of copper sulphate solution.

A mixture of copper sulphate, nicotine sulphate, and 1:8 dihydroxyanthraquinone reduced infestations with *Oe. columbianum, Trichostrongylus* spp., and *H. contortus* among sheep under field conditions. Sections of livers and kidneys showed some pathological changes persisting as long as three weeks after drenching. In Western Australia, the compound has been used effectively in a field trial to remove *Chabertia ovina* without affecting *Trichostrongylus* spp.

(v) *Drenching with the McMaster Tube.*—The anthelmintic efficiency of phenothiazine and, apparently, of piperazine, is independent of the oesophageal groove reflex, but because of their selective anthelmintic effects it may be necessary to combine them with anthelmintics which are not independent of this reflex. Accordingly, further observations on the reflex were made in sheep especially in relation to the principle of drenching with the McMaster Tube (oesophageal tube). Withdrawal of fluid through an abomasal puncture will reveal an indicator dye readily but on some occasions the abomasum cannot be readily located. Methylene blue, when swallowed into the abomasum, appears in the urine within 20-30 min., but when swallowed into the rumen does not usually appear for at least 3-4 hr. Phenothiazine appeared in the urine after 30 min. when swallowed into the abomasum, but not until after 2 hr. when swallowed into the rumen. When the mixture of copper sulphate and dye indicator was administered through a McMaster Tube, the dose was swallowed into the abomasum in only four of 24 sheep, but when the mouth was swabbed with a 10 per cent. solution of copper sulphate immediately before the tube was passed, the dose was swallowed into the abomasum in fourteen of eighteen sheep.

(vi) *Anthelmintics against Oxyurids.*—In tests of anthelmintics against oxyurids in mice, phenothiazine showed similar degrees of efficiency against *Syphacia obvelata* and *Aspicularis tetraptera.* Piperazine diacetate and phenothiazine were effective against these oxyurids; *p*-hydroxyphenothiazine, 1:4 thiazine acetate, and *N*-methyl piperazine dihydrochloride showed some activity; while the acetyl ester of *p*-hydroxyphenothiazine, *O*-ethoxyphenothiazine, *m*-chlorophenothiazine, *m*-methoxyphenothiazine, *n-n* dimethyl piperazine diacetate, monocarboxypiperazine tartrate, basic tetrahydroquinoxaline, and thiazine acetate were ineffective against these nematodes.

(vii) *Poisoning and Photosensitization with Phenothiazine.*—Although occasional cases of phenothiazine poisoning of sheep have been reported, it is a relatively non-toxic anthelmintic. Generally young animals appear to be more susceptible to it than adults. In investigations at Armidale a dose of 20 g. phenothiazine resulted in the death of lambs aged from seven to nineteen days; five died within two days of drenching, after showing incoordination, prostration, and coma with marked dorsiflexion; and three others died from one or two weeks after drenching without showing distinctive symptoms.

The incidence and severity of photosensitization in young lambs was increased following drenching with either 10 or 20 g. of ordinary coarse phenothiazine or a finely-ground preparation. The higher dose had the greater effect but there was no difference between the two preparations.

(b) Control of Fascioliasis (McMaster Laboratory).—Habitats of *Simlimnaea subaquatalis* in the Kanimbla Valley and at Oberon in New South Wales have been treated with copper pentachlorphenate. As treatments were repeated on several occasions it is difficult to assess the degree of efficiency possible by a single application with the best techniques available.

At Oberon, the habitats were treated by dusting a superphosphate "blower", and small residual areas of infestation were retreated with a hand duster a month later. As some snails still survived, the whole area was re-treated by spraying after a further four months. A small residual population remained and no great increase was seen until late the following summer. The livers of 55 lambs born in August, 1954, in the paddock in which all habitats had been treated were examined, and no evidence of damage by fascioliasis was seen.

At Kanimbla Valley the areas treated by spraying in winter showed slight residual infestations but there was no appreciable increase until late the following summer. Other areas treated in late winter, and re-treated a fortnight later, continued to harbour considerable numbers of snails.

It is clear that, if the snail population is reduced very considerably by the application of molluscicides in winter, it remains low, at least until the end of the

following summer, i.e., during the period when climatic conditions are generally most suitable for the completion of the life cycle of *Fasciola hepatica.*

(c) *Epidemiological Investigations (McMaster Laboratory and Regional Pastoral Laboratory, Armidale).*—Field studies have been conducted in southern New South Wales and in Tasmania in an attempt to discover when young sheep, naturally exposed to infestation, develop resistance to *Trichostrongylus colubriformis.* Groups of weaners were dosed with infective larvae in succeeding months and the occurrence or otherwise of resistance was assessed from subsequent faecal egg counts. No clear conclusions can yet be drawn.

After three years' observations on the epidemiology of nematode infestation of sheep in Western Australia, appropriate times for strategic preventive drenching can be recommended.

At Armidale, the previous observation that sheep on sown pasture carry lower worm burdens than those on native pasture has been confirmed. This has previously been thought to result from the higher nutritional level of the sheep on sown pasture, but work during the year has strongly suggested that it is associated rather with the greater intake of infective larvae from the native pastures. When the nutritional level on sown pastures was kept low by restricted grazing, worm burdens were not increased. On the other hand, the use of an appropriate technique for recovery of larvae from pastures has yielded calculated recoveries up to 0.5 million per acre on sown pasture compared to over 4.5 million on native pasture. Moreover, although sheep on sown pasture were previously shown to harbour lighter infestations with the nodule worm (*Oe. columbianum*) and much fewer larvae nodules in the bowel wall, when a dose of infective larvae of this species was administered to groups of sheep on sown and on native pastures respectively, the resulting infestations were similar in both groups.

Further observations on the microclimate in relation to survival of nematode eggs and larvae have been confined to a study of temperatures in faeces exposed on sown and on native pastures.

(d) *Resistance and Immunity to Nematode Infestation (McMaster Laboratory and Regional Pastoral Laboratory, Armidale).*—(i) *Initial Infestation in Relation to Resistance.*—Studies on acquired immunity to *Trichostrongylus* spp. were continued in an attempt to discover the effects of different levels of initial infestation on the development of resistance and the time required thereafter for resistance to develop. Observations are continuing and no conclusions can be drawn as yet. Some trials with lambs suggested that an initial dose of *T. colubriformis* at four weeks of age did not induce resistance but that most of those dosed initially at eight weeks of age were resistant when challenged some weeks later.

A valuable observation made in connexion with these experiments was that as many as twelve weeks may elapse after a challenge dose of infective larvae before the faecal egg count rises. During this period, the titre of the serum has usually been high and body weights have been stationary or have fallen. Two sheep killed in this condition were harbouring some 20,000 worms although their faecal egg counts were virtually negative. This confirmed a previous observation that, at times, in sheep challenged with *T. colubriformis,* egg production by the female worms is suppressed so that faecal egg counts do not indicate the degree of infestation.

(ii) *Possible Effects of Antibodies in the Ewes' Colostrum.*—The possibility that such antibodies may affect the ability of young lambs to develop resistance to worm infestation is under investigation. It has been found, both at Armidale and at the McMaster Laboratory, that lambs do not readily acquire resistance detectable by serological tests. Lambs reared under worm-free conditions and transferred while still suckling to native and sown pastures during the summer and autumn at Armidale failed to acquire infestations with *Oe. columbianum.*

(iii) *"Self-cure" Reaction.*—In further work on the mechanism of the "self-cure" reaction to *Haemonchus contortus,* the histamine level in the abomasal wall of a resistant sheep at the height of the reaction to insertion of larvae was found to be comparable to that in worm-free sheep.

(e) *Exsheathment of Infective Nematode Larvae (McMaster Laboratory).*—Infective larvae of nematode parasites of sheep were found to commence exsheathment in that portion of the alimentary tract immediately anterior to the region in which the adults are normally found. Thus, *Haemonchus contortus, Ostertagia circumcincta,* and *Trichostrongylus axei* commence to exsheath in the rumen; *Trichostrongylus colubriformis, Nematodirus spathiger,* and *N. abnormalis* in the abomasum; and *Oesophagostomum columbianum* in the duodenum. Specific differences in the rates of exsheathment were detected. A study has been made of the stability, under various temperatures, of the exsheathing factor from the alimentary tract.

The presence of a live larva within the sheath is necessary if exsheathment is to take place. Isolation of various portions of larvae from the area in which the sheath is fractured have indicated that a region in the vicinity of the base of the oesophagus is concerned in the process.

Present indications are that differences in the rate of exsheathment of *T. colubriformis* and *Nematodirus* spp. are not responsible for their different locations in the small intestine.

(f) *Route of Infestation of Strongyloides papillosus (McMaster Laboratory).*—The oral route of infection by this species is well known to be unreliable. It has been found that this can be explained, insofar as ruminants are concerned, by the lethal action of the ruminal fluid on larvae of this parasite. Infection through the skin occurs readily. When larvae are administered by the mouth it is probably only those which penetrate the adjacent skin or mucous membrane which become established in the gut as adults.

(g) *Parasite Survey (Regional Pastoral Laboratory, Armidale).*—Observations have continued with particular reference to external and internal parasites of foxes in the New England region.

No hydatid tapeworms (*Echinococcus granulosus*) were found in eighteen foxes, but two dingoes were both infested, one heavily. Examination of the stomach contents of foxes suggests that their diet makes them unlikely hosts for this tapeworm.

The following parisites have been recorded from foxes in the New England region: Cestoda—*Diphyllobothrium erinacei, Dipylidium caninum, Taenia hydatigena, Taenia pisiformis,* and *Taenia serialis;* nematoda—*Ancylostoma caninum, Toxocara canis, Trichuris vulpis,* and *Uncinaria stenocephala;* Pentastomida—*Linguatula serrata;* Acarina—*Sarcoptes scabei* (var *vulpis?*); Siphonaptera—*Ctenocephalides canis.* Final identification awaits confirmation by passage through intermediate hosts.

(h) *Parasite Physiology and Toxicology (McMaster Laboratory).*—Preliminary work has indicated that the water content of the wall of the small intestines of rats infested with *Nipostrongylus muris* is two to three times greater than in normal rats. The movements of water to and from the intestines and the rate of protein digestion in infested and non-infested rats are under investigation.

(i) *Biological Activity of Complex Ions.*—Research was continued in collaboration with the Chemistry Department of the University of Sydney. The work on anticholinesterase activity has been concluded with the following results. The cationic complexes inhibit the *in vitro* activity of the enzyme reversibly and competitively by an interaction with the anionic site of the enzyme surface. This interaction is brought about by coulombic forces. Consequently, the overall charge and its distribution on the complex are the features which determine its *in vitro* inhibitory activity. The more the positive charge is localized on the surface of the ion, the stronger is its inhibitory power.

When the anticholinesterase activity of the complexes was first compared with their toxicity to mice it seemed that the two actions were parallel but when more compounds were tested some differences were found. It was also found that eserine, a potent anticholinesterase and inhibitor of the action of curare, inhibited the lethal effect of these complexes. The toxic symptoms pointed also to a curare-like effect. The causes of the differences in enzyme inhibition and toxicity of the complexes are being investigated.

(ii) *Carbohydrate Metabolism.*—It was found earlier that some inorganic Co-complexes caused the same type of hyperglycaemia as $CoCl_2$, but without destruction of the pancreatic α-cells. Enzyme systems concerned in mobilizing liver glycogen were tested, but there was no activity of Co-complexes on them. On the other hand, dihydro-ergocornine, a sympathicolytic agent which inhibits $CoCl_2$-hyperglycaemia also inhibited the hyperglycaemia caused by inorganic Co-complexes. Hyperglycaemia caused by these agents is apparently non-specific and is caused by adrenaline liberation. The action of $CoCl_2$ on α-cells is coincidental. The presence of a hyperglycaemic-glycogenolytic "hormone" in the α-cells is open to doubt.

(iii) *Molluscicide Activity of Complex Ions.*—The molluscicidal properties of a range of complexes was examined on *Bullinus* sp. and *Simlimnaea subaquatalis.* Some of the complexes caused reversible paralysis of the snails. Homogenates from the foot muscle of these snails exhibited considerable cholinesterase activity. The enzyme involved is being purified, and a strongly active enzyme which probably belongs to the group of pseudoesterases has been isolated.

(i) *The Synthesis of Sulphonamides (McMaster Laboratory).*—(i) *The Thiophen Analogue of Sulphonamide.*—This compound is still unknown. Its succinamidic acid was prepared in an eight-stage synthesis, ultimately in good yield, and results of tests of its biological activity are still awaited. Exhaustive attempts to remove the succinic acid residue failed, probably because the free sulphonamide is incapable of free existence.

(ii) *Structure of Sulphaguanidine and Sulphanilylurea.*—All the required intermediates were prepared for the final condensation with acetylsulphanilyl chloride, but the experimental difficulties of the last step have not been overcome in all cases.

19. External Parasites.

(Division of Animal Health and Production.)

(*a*) *The Ecology of Ectoparasites (McMaster Laboratory).*—In the last Annual Report the oviposition behaviour pattern of *Damalinia ovis* was described. This work has been continued. It has been found that *D. equi* and *D. ovis* have similar oviposition behaviour patterns governed by similar critical factors. With *D. equi* fibre diameter is the most important ecological factor. It can attach its eggs only to the fine fibres of a horse's coat and when these hairs are shed in spring, about 70 per cent. of the louse population can be lost in consequence. Thus, any factor such as poor nutrition which may delay the shedding of the coat will result indirectly in an increase in the louse population.

Reasons are being sought for the difficulty in hatching large numbers of eggs of *D. ovis* in the laboratory. It was found that starvation of the females greatly reduced the fertility of their eggs and further possible factors are being studied.

It was found that *Epidermoptes bilobatus,* obtained from a turkey poult, attached its eggs to the skin by a small strap-like stalk. Such a mode of attachment has not been observed in an external parasite previously.

A study of fleece temperature made at "Gilruth Plains" was interrupted by rain. However, fleece-tip temperatures of about 160° F. were recorded when the air temperature was 111.4° F. Further data on the effect of solar radiation on the temperature conditions of the fleece are required to assess its significance in the ecology of ectoparasites.

(*b*) *The Itch Mite* (Psorergates ovis).—BHC at the rate of of 50 mg. per kg., and dieldrin at 100 mg. per kg. were given subcutaneously in peanut oil to sheep infested with *Psorergates ovis.* After four weeks there was no effect on the infestation. The sheep given BHC subsequently died, but the sheep given dieldrin was still infested four months later. Oral administration of arsenic to sheep was abandoned because lethal doses were necessary before significant concentrations of arsenic could be detected in the skin. Direct injection into the rumen also failed.

20. Protection Against Blowfly Strike.

(Division of Animal Health and Production.)

(*a*) *Protection of Sheep Against Body Strike (Veterinary Parasitology Laboratory).*—Investigations have continued, in co-operation with the Queensland Department of Agriculture and Stock, on the value of various insecticides applied to the fleece to protect sheep against fly strike. The effect of systemic administration of insecticides is also being investigated.

In addition to the observations in the insectary at Yeerongpilly, several field trials were instituted.

The addition of arochlor did not increase the persistency of dieldrin, aldrin, or BHC when applied by jetting. Further trials confirmed results previously reported, namely, that dieldrin and aldrin are more effective than BHC. Nevertheless, in view of results in one trial, the possibility that dieldrin and aldrin may be leached from the fleece at a faster rate than BHC when heavy rain is experienced is now being investigated. Two series of field trials with aldrin, dieldrin, and BHC, involving treatment of over 1,400 sheep, were carried out in central Queensland, but seasonal conditions prevented the occurrence of body strike. Later some 5,000 sheep were treated in southern Queensland, but again seasonal conditions rendered the trials abortive.

Field observations indicate that dieldrin, aldrin, or BHC (0.1 per cent.) are effective when jetted into and around struck areas, without removal of the wool.

The subcutaneous injection into sheep of aldrin, dieldrin, or lindane in peanut oil has not given promising results in preliminary trials concerning protection by this means against blowfly larvae.

(*b*) *Lamb-marking Dressings (Regional Pastoral Laboratory, Armidale).*—Both "Borocit" and 0.1 per cent. dieldrin gave good results in prevention of blowfly strike following lamb marking. Although "Borocit" proved slightly superior in preventing actual strikes, there was no tendency for strikes to spread from the docking wound with either treatment.

21. Other Sheep Investigations.

(Division of Animal Health and Production.)

(*a*) *Clover Oestrogens.*—Work in Western Australia has shown that in saponified extracts of chloroplast material from subterranean clover there is, in active fractions, a phenolic oestrogen which is distinct from genistein.

(*b*) *Phalaris Staggers.*—An outbreak of phalaris staggers occurred at "Chiswick", Armidale, New South Wales, during the winter of 1954 on a phalaris-white clover pasture on a lateritic soil. Previously this trouble had been experienced near Armidale only on granitic soil. Romney Marsh weaners, but not Merinos, were affected. Examination of rumen contents showed no breed difference in grazing selectivity; phalaris had comprised 80 to 90 per cent. of the diet of both breeds.

(*c*) *Production of Native Pastures Used in Conjunction with Sown Pastures.*—In co-operation with the Division of Plant Industry, at "Chiswick", Armidale, a study is being made of the animal and pasture production from land units composed of increasing proportions of sown pasture (3.9, 15.5, 30.8, and 57.1 per cent.), with composite flocks of breeding ewes, weaners, and wethers.

Results from the first and second years of the trial are beginning to reveal the range of increases in overall production per unit area which may accrue as the percentage of sown pasture increases. For example, the wool production and liveweight increases in 1954 were 21 lb. wool and 53 lb. liveweight increase per acre when 57.1 per cent. of sown pasture was available, compared to 9 lb. wool and 3 lb. liveweight increase per acre with only 3.9 per cent. of sown pasture.

(*d*) *Utilization of a Sown Pasture Supplement in Conjunction with Native Pastures.*—Different methods of utilizing a given amount of sown pasture by grazing for different times and intervals are being investigated.

(*e*) *Potential Liveweight Increases of Merino Sheep.*—Since March, 1954, two groups of fine-wool non-Peppin Merino wethers born in 1953 have grazed the best available crops or pastures on "Chiswick", in an attempt to establish potential growth rates for this class of stock. From a mean weaning weight of 47 lb. in March, 1954, the sheep reached 102 lb. by March, 1955. Generally the best weight gains made in any one month were associated with pastures containing a large proportion of legumes. A subgroup, drenched monthly with phenothiazine, showed a very slightly higher trend in liveweight but parasite infestations in both treated and untreated sheep were low throughout.

22. Controlled Climate Rooms.

(Central Experimental Workshops.)

Provision has been made in the new Sheep Biology Laboratory being constructed at Prospect for a climate control building in which the effects of climatic variations on the behaviour of sheep and cattle will be studied. The building will contain initially two insulated rooms, each 27 feet by 14 feet by 8 feet high, in which the animals will be housed and in either of which temperature and humidity can be accurately controlled at any point within an extremely wide range. The conditions, in effect, can be set to reproduce the normal maxima or minima which occur in any part of Australia.

Owing to the size and special aspects of the project, a prototype room was built at the Central Experimental Workshops and tested extensively to obtain design data and to prove novel features before their incorporation in the final design. Valuable advice was also received from Dr. Brody and Professor Stewart of the University of Missouri, who visited Australia early in the year to report on the project and to give the Organization the benefit of their own extensive experience on work in this field.

Construction of the final equipment at Maribyrnong and its installation at Prospect is now nearing completion, and an extensive programme of testing is being put in hand. Some time will necessarily elapse before animals can be installed in the rooms and the proposed research programme initiated.

VIII. CATTLE.

1. General.

Products of the cattle industry—meat, hides, and dairy produce—represent over 20 per cent. of all Australian rural production. With the rapid increase in the population of Australia in the post-war period, home consumption of food commodities is outstripping primary production. If Australia is to maintain both its own food standards and an export of meat and dairy products on the pre-war level, research must find the means to increase the entire cattle industry.

Broadly, the approach of the Organization to the problems of the cattle industry comprises:

(i) A survey of the structure and interrelations of the various sections of the beef cattle industry throughout Australia.

(ii) Studies designed to eliminate wastage and loss from disease in both beef and dairy cattle.

(iii) The exploitation of potentialities for improving nutrition by the development of sown pastures; scientific understanding of the characteristics and management of natural pasture and study of the possibility of introducing desirable exotic species into natural pastures.

(iv) The development of systems of breeding designed to evolve more productive beef and dairy types for north Australian conditions.

The Organization's work on cattle problems has been carried out chiefly by the Division of Animal Health and Production, mainly in the Animal Health Laboratory in Melbourne, the National Cattle Breeding Station at "Belmont", near Rockhampton, Queensland, and the Veterinary Parasitology Laboratory in Brisbane, Queensland (*see* Sections 2, 3, 4, 6, 7, and 8 of this Chapter). The Division of Entomology has been concerned with work on the cattle tick (*see* Section 5 of this Chapter). The work of the Division of Plant Industry on pastures is also of great importance to the cattle industry (*see* Chapter III.). The work of the Animal Genetics Section on beef cattle is described in Sections 8 and 9 of this Chapter.

2. Cattle Diseases.

(Division of Animal Health and Production.)

(*a*) *Pleuropneumonia of Cattle* (*Animal Health Laboratory, Melbourne*).—On properties in northern Australia, where bovine pleuropneumonia is firmly entrenched, it has been suggested that routine annual vaccination of all mustered cattle, including calves, may gradually reduce the incidence of, or even eliminate, the disease over a period of years. However, as mentioned last year, it was found that severe, crippling joint swellings and sometimes valvular lesions in the heart occurred in calves vaccinated at ages up to 50 days. During the current year it has been found that calves even seven days old develop effective immunity. Nevertheless, as the risk of losses as a result of vaccination is considerable, it is advisable in the present state of knowledge to restrict vaccination to calves not younger than about two to three months.

Much attention was given to the problem of deterioration of vaccine. Whereas fresh vaccine containing 10^9 living organisms per ml. immunized satisfactorily, the same vaccine diluted 1,000-fold failed to immunize. Decrease of viability of this order has not been observed under conditions of good storage (4° C.) within two months, but at 25 and 37° C. deterioration is more rapid and more severe. For this reason, the expiry date of vaccine has been strictly fixed at two months after manufacture. In the "Instructions for Use", emphasis has been placed upon keeping vaccine cool and away from sunlight. During the year 446,000 doses of vaccine were distributed, and sufficient complement-fixing antigen was supplied to laboratories within Australia and abroad to permit the testing of 40,000 cattle.

In addition to general studies on the disease, the growth requirements of the causal organism *Asterococcus mycoides* and of some of its metabolic products are being intensively studied.

(*b*) *Mastitis in Dairy Cattle (Animal Health Laboratory, Melbourne)*.—Extensive research on streptococcal mastitis has been discontinued. Observations on the experimental dairy herd at the Werribee Field Station have confirmed reports that a closed herd will remain free from further infection once *Str. agalactiae* has been eliminated. This is not so with straphylococcal infections, and treatment with various antibiotics usually failed to remove these organisms from infected udders, especially if chronically affected. Work is proceeding on the differentiation of pathogenic staphylocci from non-pathogenic cocci derived from bovine udders. Co-operative work has been commenced with the Commonwealth Serum Laboratories to ascertain whether inoculation with staphylococcal toxoid will protect against udder damage by staphylococci.

(*c*) *Brucellosis in Cattle (Animal Health Laboratory, Melbourne)*.—Long-term experiments with strain 19 vaccination have been continued to assess the degree and duration of the protection it affords. It has previously been reported that most animals which resisted infection at the first challenge to immunity continued to do so on subsequent occasions including that during pregnancy in the fifth year after calfhood vaccination; furthermore, there was no significant difference between animals vaccinated only during calfhood and those subjected to a second vaccination three years later. Animals which had proved resistant have now been subjected to a further challenge six years after calfhood vaccination but, on this occasion, to simulate natural conditions, instead of submitting cattle to the risk of infection in paddocks contaminated by aborting cattle, a measured dose of a virulent strain of *Br. abortus* was introduced. The dose used (13.5 million organisms) proved too small to produce a high abortion rate as only two of twelve control animals aborted; however, eight were found to be infected at the time of calving. By comparison, infection was shown by none of eighteen animals which had been vaccinated only during calfhood, and by only one of eighteen that had been vaccinated again three years later. Thus, after some animals, presumably of high susceptibility, were eliminated from further tests because they became infected at the first challenge, most of the remaining animals were resistant to infection for some six years following calfhood vaccination, and revaccination after three years appeared to serve no useful purpose. General studies on the disease were continued. It is of interest to note that in some control cattle, proved to be infected at the time of parturition, virulent *Br. abortus* was isolated from udder secretion for as long as two months before parturition, and in the absence of any strong evidence of infectiou as judged by the results of serum agglutination tests.

(*d*) *Haematuria Vesicalis of Cattle (Animal Health Laboratory, Melbourne)*.—Consideration of comparative aspects led to the hypothesis, now being investigated, that haematuria vesicalis in cattle may result from the presence in the bladder of irritant substances chemically related to known carcinogens.

(*e*) *Infertility in Dairy Cattle (Animal Health Laboratory, Melbourne)*.—A survey of this problem is being made by the several States and C.S.I.R.O. is filling a co-ordinating role. In addition, investigations have been carried out in some selected "problem herds" in Victoria. In one such herd infection with *Trichomonas foetus* was found to be widespread and the diagnosis was confirmed by microscopic and cultural examination of specimens from cows and bulls. It seems probable that this disease may be one important cause of temporary infertility in Victoria. Reports from workers in the State Veterinary Research Laboratories of New South Wales and Queensland have already indicated its importance in some large dairying districts there. The Victorian strain of *T. foetus* and one obtained from New South Wales appear to be of the same serological type and to correspond to the "Belfast" type obtained from the United Kingdom.

3. Internal Parasites.

(Division of Animal Health and Production.)

The following investigations were carried out by the staff of the Veterinary Parasitology Laboratory, Queensland:—

(*a*) *Parasitic Gastro-Enteritis of Cattle.*—(i) *Seasonal Trends in Helminth Populations.*—During the year three herds were under trial, two in south-eastern Queensland and one in Victoria. In the Queensland herds the population trends, as judged by faecal egg counts, of *Haemonchus placei, Cooperia* spp. (*C. pectinata* and *C. punctata*), *Bunostomum phlebotomum*, and *Oesophagostomum radiatum* have continued to conform to the patterns previously reported, and it is considered that trials in this State may now be brought to a close. The herd in Victoria has been under observation since 1952, and in this part of Australia *Ostertagia ostertagi, Trichostongylus axei*, and *Cooperia oncophora* have been the most prevalent species. Some indication of the seasonal trends in these species has already been reported, but observations will be extended to confirm this. Assistance was also provided to the Department of Agricultnre, Western Australia, for similar work in that State.

(ii) *Natural Infestations in Cattle and Circulating Antibodies.*—An attempt to correlate the presence and concentration of circulating antibodies with egg counts in a group of calves, which first came under observation when a few days to a month old, showed that—

(1) circulating antibodies may be present in newly born calves and may persist for about a month, but may not be detected thereafter until the animal is four to six months of age and sometimes older;

(2) in animals with moderate to high worm counts, but which show good resistance, the antibody titre may be persistent with a tendency to increase immediately prior to the manifestation of resistance to H. *placei;*

(3) in animals which succumb to parasitism when six to eight months old or less, antibodies may not be detected except during the first month of life;

(4) in animals which become resistant but later lose their resistance and die, antibodies may be present only during the period when resistance is developing.

(iii) *Studies on Infestation with* Haemonchus placei.—Attempts to ascertain the factors responsible for haemonchosis in cattle have included observations on both natural and experimental infestations. Most calves exposed to natural infestation develop a strong resistance and throw off the infestation, while others only become resistant after suffering clinical "haemonchosis". Some 10 per cent. either fail to develop resistance or lose their resistance, and these die unless treated. Most of the fatalities and cases of clinical haemonchosis occur in winter and early spring when infective larvae are abundant and the nutritional value of pastures is low. Experiments with worm-free calves were undertaken to study the effect of varying the intake of larvae and the nutritional status of the animal.

When calves were fed on lucerne chaff, single doses of up to 50,000 larvae, repeated daily doses of up to 10,000, or spaced doses of 50,000 to 250,000 larvae, only produced low faecal egg counts, of short duration, after some six to eight weeks. Subsequent challenge doses of larvae indicated that all these calves had developed a high degree of resistance. When the experiments were repeated with calves receiving a ration of twelve parts oaten chaff to one part lucerne chaff, these showed very much higher eggs counts but the infestation did not persist longer and the calves became equally resistant. These results contrast strongly with those obtained with *Haemonchus contortus* in sheep, in which the infestation persists for long periods and the development of resistance is erratic and relatively infrequent. The occurrence of numerous immature worms in some calves which, according to their faecal egg counts, had become strongly resistant, indicated the importance of these stages of nematode parasites in the epidemiology of helminthiasis. It has been suggested that treatment with anthelmintics may hinder development of resistance. In calves given spaced doses of larvae and treated with phenothiazine, development of resistance appeared to be delayed in some cases.

(iv) *Haematology and Biochemistry of Calves Infested with* Haemonchus placei.—These studies were made on two groups of worm-free calves, one fed on lucerne chaff and the other on a 12:1 mixture of oaten and lucerne chaff.

In both groups haemoglobin levels commenced to fall within two weeks of infestation and reached a minimum of 38 to 49 per cent. of their initial values five to seven weeks after infestation. There was a slight increase thereafter, but after fourteen weeks, when the infestations had decreased to low levels, the haemoglobin level was still subnormal. Haematocrit values and erythrocyte counts roughly paralleled the haemoglobin levels. Total serum protein levels remained relatively constant.

In the group fed on the chaff mixture, serum inorganic phosphate declined slowly to minimum values of 4.0 to 5.0 mg. per cent. by the ninth to eleventh weeks, but increased appreciably two weeks later. Serum calcium remained relatively constant except for a compensatory rise, while serum inorganic phosphate was low. The calves on the lucerne chaff showed no significant variation in serum calcium or inorganic phosphate.

(v) *Reactions of Cattle to Infestation with* Haemonchus contortus.—In a herd of calves exposed to natural infestation with both *H. contortus* and *H. placei*, infestation with *H. contortus* was always smaller than with *H. placei*, and resistance to *H. contortus* occurred at a much earlier age than resistance to *H. placei*. Furthermore, infestations of *H. contortus* were completely eliminated, whereas those of *H. placei* persisted. Evidently cattle are not as suitable hosts for *H. contortus* as for *H. placei*.

(vi) *Anthelmintics.*—One herd of calves, one to two months of age, was treated at intervals of four weeks with phenothiazine and another with tetrachlorethylene preceded with sodium bicarbonate. Both treatments effectively controlled *H. placei*, but not *B. phlebotomum* or *Cooperia* spp. The effect on *Ostertagia* spp. and *Trichostrongylus* spp. was doubtful as they were present only in small numbers. There was no indication that the calves treated with either anthelmintic gained weight better than the controls, despite the presence of moderate to heavy infestations.

(vii) *Ecology of the Preparasitic Stages of Cattle Strongyles.*—These studies were continued and included observations on larvae on experimental plots and on naturally infested pasture.

1. *Larvae on Experimental Plots.*—When faeces from calves infested with *H. placei* were exposed under natural conditions on uncontaminated pasture plots (mostly grasses) during the period August to December, larvae reached the infective stage in ten to fourteen days. Migration from the dung then commenced and one to two weeks thereafter the numbers of larvae in the soil and the mat were about equal, with some 60 per cent. present on the herbage. Lateral migration up to 12 inches from the pat, the maximum permitted by the size of the plot, occurred within a few days after the larvae reached the infective stage. They appeared in maximum numbers by the end of the second week, and by the fourth week a decrease of 80 to 90 per cent. was recorded. Larvae were found in the soil to a depth of 1.5 inches. Little rhythmic vertical migration was apparent, nor did the number of larvae on the pasture appear to be influenced by time of the day. Of the larvae recovered from the plots at different times of the day, some 80 per cent. were found 6 inches or more above the soil.

Plots sampled at monthly intervals after exposure showed that at two months the recovery was about 80 per cent., at three months 15 per cent., and at four months only 3 per cent. The plots were virtually free of larvae after 150 days.

2. *Studies on Larvae on Naturally Infested Pasture.*—These studies are only in a preliminary stage. Results to date show that, at least with *Cooperia* spp. which were present in greatest numbers, the larvae were numerous in winter and scarce in summer. The high winter population is believed to be due to a gradual accumulation of larvae, whose longevity is favoured by the lower temperatures.

(viii) *Infectivity of Strongyle Larvae.*—It has been suggested that infectivity of strongyle larvae may be associated with the fat content of their intestinal cells. In work with the infective larvae of *H. placei*, it was found that fat disappeared entirely from the intestinal cells after fourteen days at 26° C., whereas at 8-9° C., little change occurred. These observations will be continued and the infectivity of the larvae will be tested by feeding them to worm-free calves. More detailed observations will be made on a strain of *Nematospiroides* in mice.

(*b*) *Worm Nodules* (Onchocerca gibsoni).—Further attempts have been made to distinguish the microfilariae of *Onchocerca gibsoni* from those of *O. gutterosa*, both of which occur in the skin of cattle. No differences either in morphology or in the development and arrangement of the nuclei could be detected between the newly born and skin-inhabiting forms of each species, indicating that the larvae of *Onchocerca* spp. are mature when born and undergo little, if any, change, between birth and migration to the skin.

The form, size, and arrangement of the caudal and cephalic nuclei were found to vary widely within each species. Of the many measurements made only body length was found to have taxonomic value. Microfilariae of *O. gibsoni* measured 240-280 μ (mean 266 μ)

in length, whereas those of *O. gutturosa* measured 200-260 μ (mean 224.5 μ). This finding will be of great assistance in further work on the beef nodule problem.

(*c*) Haemonchus Contortus *of Cattle and Sheep.*—Cytological studies based on aceto-orcein squashes of the gonads showed the existence of large sex chromosomes in the form from sheep and small sex chromosomes, equal in size to the autosomes, in the form from cattle. In an experiment designed to ascertain whether interbreeding occurred, only 4.3 per cent. hybrids were found among the females and these proved fertile. In a natural mixed infestation in calves, the percentage of hybrids among the females was only 7 per cent. That such small numbers of hybrids were found indicates the existence of some fertility barrier. This reluctance to interbreed, the observed differences in karyology, and the existence of some degree of host specificity, together with the morphological differences previously recorded, are regarded as adequate evidence that the two forms represent distinct species.

(*d*) *Liver Fluke.*—Whether species of lymnaeid snails, other than *Simlimnea subaquatilis,* are involved as intermediate hosts of *Fasciola hepatica* in Australia, remains in doubt until the taxonomy of this family has been thoroughly explored. Closely allied species cannot be clearly defined on appearance and on measurements of the shell. In the past years, examination of the ovotestes revealed that chromosome numbers were unlikely to be of toxonomic value and that chromatographic examination of foot tissue, which reveals distinctive patterns in various species of land snails, revealed a similar pattern in different species of aquatic snails by the methods used. The work is continuing.

4. The Cattle Tick.

(Division of Animal Health and Production.)

Investigations concerned with the effects of ticks on cattle are continuing at the Veterinary Parasitology Laboratory, Queensland.

(*a*) *Host Reactions to Tick Infestation.*—Studies to compare the reactions to infestation with the cattle tick *Boophilus microplus,* of British breeds of cattle (*Bos taurus*) and of Zebu cattle (*Bos indicus*), were commenced. Until purebred Zebus become available, initial observations are being made on Zebu/Shorthorn crossbreds with at least 5/8 Zebu blood. The British breeds are represented by purebred Shorthorns. Five animals of each breed are being artificially infested in pens with 20,000 tick larvae at intervals of two to eight weeks. At each alternate infestation the animals are prevented by an anti-licking harness from removing ticks. Blood samples are being taken at the beginning and end of each infestation, when the animals are also weighed. Food intake is also under observation.

All animals showed some degree of hypersensitivity and the yield of engorged female ticks when the anti-licking harness was applied was always significantly greater than in its absence. The yield of engorged female ticks from the Zebu crossbreds was significantly smaller than from the Shorthorns. The average numbers per infestation obtained from the Zebu crossbreds to date were 484 and 179, the former figure being obtained when the anti-licking harness was used; comparable figures from the Shorthorns were 1,516 and 711 respectively. Furthermore the development of ticks on the Zebus to the engorged female stage was retarded and many survived only for two or three days in the adult stage. The engorged females from the Zebus were slightly smaller than those from the Shorthorns and produced fewer eggs.

Among the five Zebu crossbreds three have the appearance of Zebus and these showed the greatest resistance to infestation. The other two which were less resistant had a greater resemblance to the Shorthorn.

As yet, the infestations have had no significant effect on the blood picture. It is of interest that the Zebu cross-breds showed a much higher red cell count and per cent. haemoglobin content than the Shorthorns. Such animals should be better able to withstand the effects of tick infestation in consequence. Preliminary examinations of skin sections have shown no significant differences in thickness or in the sweat or sebaceous glands.

Studies have also been commenced on the artificial sensitization of the skin of calves with extracts of eggs of *B. microplus* to ascertain the effect of any resulting reaction on subsequent experimental infestations. Such calves have continued to give positive reactions for up to four months to intradermal skin tests with egg antigeu at a dilution of 1 : 10,000.

(*b*) *Tick Toxins.*—Injections into guinea pigs of water-soluble protein fractions, prepared from eggs of *Boophilus microplus* by salt fractionation, indicated that at least two distinct toxins are present. One of these appears to be a simple globulin and the other a haematin-globulin compound. When the haematin moiety of this compound was split off by acid-acetone treatment, injection into guinea pigs of the pigment-free globulin showed that the protein still possessed its toxic properties. Attempts to discover the function of this haemoprotein in the eggs or in unengorged larvae were unsuccessful.

5. Biology and Control of the Cattle Tick.

(Division of Entomology.)

The chemical control of the cattle tick remains an important aspect of work on this problem. Marked progress has been made in the study of BHC and DDT dipping fluids, the oldest-established and still the most widely used of the "modern" acaricides. The problem of tick resistance to acaricides still looms large in the toxicological field, but laboratory and field studies have resulted in marked progress in knowledge of the phenomenon. Some promising new toxicants have been tested under field conditions, and further studies made with the injection of insecticide solutions into the bodies of cattle.

Studies on methods of grazing management have given indications that greatly improved cattle tick control can be obtained whenever it is practicable to destock pastures for from three to five months according to the local climatic and pasture conditions. The more effective employment of dipping in relatiou to knowledge of the seasonal life history of the cattle tick has also received strong emphasis, while biological studies relevant to the understanding of the ecology and control of the tick have also been made.

(*a*) *Chemical and Biochemical Studies.* — (i) *Laboratory Toxicity Trials.*—The technique for this work has been reviewed, particularly in regard to larval dipping trials, and its employment in the investigation of toxicological problems has been intensified.

(ii) *Depletion of Gamma-BHC from Dipping Vats.* —The differential loss of gamma-BHC as against the remaining, less toxic isomers of BHC is a serious problem in the maintenance of dip efficiency. Laboratory tests have indicated that the purified gamma isomer of BHC (lindane) was progressively destroyed in suspensions of cattle dung and soil, constant contaminants of dipping fiuids. The rate of destruction of gamma-BHC increased with increase in temperature up to 100° C., and with increase in concentration of faecal material. The destruction of gamma-BHC continued, but at a reduced rate, after such suspensions had been autoclaved to ensure the destruction of micro-organisms. Some soils increased the rate of break-dowu, and others were without effect. Certain chemicals

inhibited the break-down and in nearly all cases this appeared to be associated with the lowering of the pH of the mixture.

(iii) *DDT Formulations.*—To assist in the selection of the most suitable DDT formulation for eradication campaigns, an experiment was commenced in southern Queensland in which two herds were dipped in 0.5 per cent. *pp*1-DDT asa colloidal preparation and a wettable powder respectively. Care was taken to ensure that the pastures were infested with seed ticks, as the main object of the experiment was to determine whether, in the face of continuous potential infestation, either of the formulations used fortnightly permitted any adult ticks to mature and lay viable eggs. Differences in the rate at which the two formulations cleared up the original infestations were marked. The cattle dipped in the wettable powder shed large numbers of fertile ticks after the first dipping, and were not completely freed of the initial infestation until the third dipping, a month after the first. Those dipped in the colloidal preparation, however, cleaned up much more rapidly, and were freed of ticks by the second dipping. Small numbers of fertile ticks matured and fell from the cattle during most of the intervals between twelve fortnightly dippings in the wettable powder, whereas in the colloidal-type dip no fertile ticks were recovered subsequent to the clean-up of the original infestation.

Chemical analyses of hair clipped from animals of both herds immediately before and after dippings showed interesting differences between the residual deposits from the two formulations. On cattle dipped in the wettable powder, the rise in the DDT deposit immediately on dipping in the fall a fortnight later, immediately before the next dipping, followed a constantly recurring pattern, the immediate post-dipping deposit appearing to vary with the small variations in the DDT concentration in the dipping vat. In the colloidal preparation the post-dipping hair deposits from the newly-charged vat were relatively low, but the deposits after the second dipping were about five times as great. The hair deposits from this preparation also tended to be highest following dippings carried out a fortnight after the vat had been topped with fresh concentrate, and not on the day when the concentrate was added.

(iv) *DDT-resistant Ticks.*—Difficulty in controlling ticks with DDT was reported from two properties in central Queensland. Laboratory dosage-mortality trials with larvae and engorged ticks from both places gave positive evidence of slight resistance to DDT in these strains.

(v) *Toxaphene.*—A study was made of a herd in southern Queensland dipped in a vat containing 0.5 per cent. toxaphene as an emulsion. The kill of ticks was rapid and complete, and a protective period of three weeks against larval attachment was afforded. The ticks on this property had never been exposed to any toxicant except arsenic, to which they were still susceptible.

(vi) *Toxaphene-resistant Ticks.*—Previously it was reported that a strain of BHC-resistant ticks exhibited a degree of resistance to chlordane, dieldrin, toxaphene, and DDT, to which the strain had never been exposed. Field evidence of this phenomenon of general resistance being associated with the development of resistance to one acaricide was obtained in southern Queensland. The ticks on a property had earlier developed a resistance to BHC, and when the vat was charged with 0.5 per cent. toxaphene emulsion, the cattle could not be freed of ticks, and protective periods against attachment of seed ticks amounted to only a few days. Laboratory dipping trials confirmed the toxaphene resistance of these ticks. Complete kills of ticks were obtained on cattle brought from other properties where BHC resistance had never developed.

(vii) *Dieldrin.*—Further spraying trials were carried out with this acaricide, employing an emulsion with "lissapol" NX, xylol, and carbon tetrachloride for comparison with an emulsion incorporating a formaldehyde resin, which had been designed to enhance the persistency of the deposit. No greater persistency was observed in the latter, but both formulations indicated once again that dieldrin is an excellent acaricide, with persistency superior to that of DDT.

(viii) *Malathion.*—This substance is an organic phosphate of relatively low toxicity to vertebrates. As a group, organic phosphates are characterized by low persistency, but possess the advantage that arthropods have been known to develop only a low order of resistance to them. A wettable powder of malathion was sprayed on to cattle at concentrations of 0.5 and 1.0 per cent. The kill was very nearly complete, and there was an apparent protective period of about six days.

(ix) *Diazinon.*—This material is also an organic phosphate of low toxicity to vertebrates. At concentrations of 0.05 and 0.1 per cent. a complete kill of ticks was secured in spraying experiments. The residual effect was not more than four days, but the material is excellent for the destruction of ticks resistant to chlorinated hydrocarbons.

(x) *Chlorthion.*—This organic phosphate was first applied to cattle as a wettable powder at 0.01 per cent. chlorthion. The kill was poor, and larvae were found to be attaching once more to the cattle three days after spraying. Raising the concentration to 0.1 per cent. gave a rather better kill, though the survival, particularly of nymphs of all stages, was higher than desirable. Protective period was not increased at this concentration.

(xi) *Systemic Application of Acaricides.*—DDT, lindane, dieldrin, and aldrin were dissolved in peanut oil, and injected subcutaneously into tick-infested cattle at the rate of 25 mg. of acaricide per kg. of body weight. At this dosage DDT produced no detectable effect on cattle tick infestation. On lindane-injected animals, on the other hand, no live larval ticks were present seven days after injection. Live nymphs and adults were still present, however, but although a considerable number of these stages developed to maturity, they appeared to suffer some mortality in comparison with the corresponding stages on untreated animals. The animals injected with lindane were completely protected from the attachment of seed ticks for fourteen days after injection. Seed ticks attaching for some days after this underwent some engorgement, but ultimately died, and the mean protective period calculated from the first appearance of young adult ticks was 22 days. Animals injected with dieldrin usually became free of larval ticks in about fourteen days, and the period of freedom from larval ticks was not so well defined as with lindane. However, the effect was more persistent, and the main protective period calculated as above was 33 days. Aldrin injections were slower in producing effects on the ticks than were dieldrin injections, and left more survivors, but effects were more persistent. For three weeks after the animals were injected with aldrin the tick infestation became lighter, and the animals carried a minimum of larvae on about the twenty-first day. There was no clear protective period because there seemed to be a continuous overlapping succession of non-persistent larvae. However, young adult ticks did not appear on the cattle until the sixty-third day after injection, and so, allowing fourteen days for the attainment of this stage, it appears likely that the effective protective period was 49 days.

(*b*) *Biological, Pasture-spelling, and Dip-timing Studies.*—(i) *Larval Survival.*—The observations on the survival of the non-parasitic stages of ticks at Rockhampton and Yeppoon in Central Queensland

were concluded at the end of November, 1954, and the two years' results have been recorded in convenient graphical form.

(ii) *Pasture Spelling.*—The experiment at Rockhampton on the effect of controlled grazing on tick infestation was concluded at the end of November, 1954. Destocking of pastures for three months in summer and five months in winter gave very low tick infestations, and between February and November only one spraying was carried out on the lightly infested cattle on controlled grazing, whereas four sprayings of the cattle on continuously grazed pasture were necessary. The assistance of graziers near Gladstone and Townsville has been enlisted to test the same principle on a larger scale. A herd of 400 cattle at Gladstone dipped on 14th January, 1955, and put into a paddock spelled since the previous October, were very lightly infested on 21st April, 1955.

(iii) *Seasonal Timing of Dipping.*—Investigations have continued on the intensive spring and early summer dipping of cattle to deplete the seed tick population arising from the first post-winter generation of ticks, the fall of which after the winter population trough is necessary to continue the immunization of the cattle against redwater. In the previous season marked success was achieved by this method in preventing the summer build-up of seed tick populations, so that it was possible to relax dipping during the summer months, when under usual conditions of management it must be intensive. During the 1954-55 season, results were not so clear-cut. In general, efficient control was maintained on the "strategically dipped" herds, but it was not possible to relax the summer dipping as previously. The reasons for this are fairly well understood. It is known that tick-infested cattle were inadvertently introduced to some herds at a critical period, and allowed to drop ticks, which reinfested the pastures with seed ticks.

(iv) *Sampling of Larval Populations.*—A test of various devices for sampling larval populations in the field was carried out over an area seeded with a known number of larvae. The most satisfactory device collected more than one-twentieth of the larvae encountered.

(v) *Tick-free Areas.*—Further information has been collected on ant predation and other factors which might affect ticks at two areas said to carry low tick infestations compared with surrounding country. The brown house ant (*Pheidole* sp.) has been added to the list of ants attacking ticks in the field.

(vi) *Toxic Principle in Hair of Undipped Cattle.*—In laboratory toxicity trials with hair clippings from animals in an acaricide trial, there was considerable mortality amongst larvae confined to hair from an untreated animal. Similar effects were obtained with hair samples clipped from other animals which had been undipped for a long period.

6. Investigations with Dairy Cattle.

(Division of Animal Health and Production.)

(*a*) *Progress in the Zebu-cross Dairy Herd (McMaster Field Station).*—Attempts to improve the fertility of the Sindhi Jersey bull have been unsuccessful and only thirteen calves have been bred from him since 1952. This has retarded progress. A number of Jersey heifers with good production background have been purchased and will be inseminated from the Sindhi and Sahiwal bulls obtained from Pakistan to establish a crossbred dairy herd.

Data on lactation performance, coat colour, and body weight of the present crossbreds are being recorded. The production performance of crossbreds obtained from the beef-type Zebu bull on dairy breeds is disappointing compared with that from purebred milking types.

(*b*) *Coat-shedding Studies (McMaster Field Station).*—Preliminary results suggest that the initial change in the coat at commencement of shedding is a sudden one. The rich appearance of the winter coat changes to a dry, rough condition, but the hairs at this stage are still firmly held in the follicles and the distribution of fibre lengths is unchanged. Shedding soon commences, first along the neck and at the back of the thigh, followed by a strip along the mid-line of the back. It then becomes general. Physical condition of the animal and lactation appear to affect the rate of shedding. Animals in poor condition and those at the peak of lactation shed their coats relatively slowly.

7. Beef Production in Australia.

(Division of Animal Health and Production.)

(I.) The following studies are under the direction of the William McIlrath Fellow in Animal Husbandry, with head-quarters at the McMaster Laboratory:—

(*a*) *Investigations in the Southern States.*—These investigations were conducted in collaboration with the Departments of Agriculture in New South Wales, Victoria, South Australia, Western Australia, and Tasmania. The observations at twelve centres, established with funds provided by the Australian Meat Board, were continued. Much useful information is being collected on the seasonal fluctuations in body weight gains. Some progeny-testing projects are in progress.

(*b*) *Yard Feeding of Steers.*—Yard-feeding studies with steers were commenced to investigate methods whereby the utilization of low-quality roughages could be improved and to indicate sound economic methods of supplementary feeding, or even complete hand feeding, during periods of nutritional stress.

Twenty-five crossbred Aberdeen Angus steers were hand fed for 109 days on oaten hay (5.2 per cent. crude protein), and later on oaten hay plus 3 lb. per head per day of a mixed supplement which contained 22 per cent. crude protein. During this period, average dairy live-weight increase was 1.64 lb. per head per day.

(*c*) *Stall Feeding of Steers.*—Seventy-nine Devon Shorthorn steers were stall fed for periods from 23 to 84 days. Seven groups were fed on rations of grass-clover hay, oats, and meatmeal, one group on hay, oats, and high-quality grass-clover silage, and one group virtually on silage only.

Complete data were collected on live-weight gains, food consumption, and estimated carcass gains. The results demonstrated the value of high-quality silage as a suitable production fodder, and showed that silage can be fed successfully and profitably at current beef prices.

(*d*) *Feeding Stud Cattle.*—Complete nutritional and live-weight data continue to be collected from a Hereford stud.

(*e*) *Supplementary Feeding Experiments.*—Feeding studies were carried out in co-operation with the Veterinary School of the University of Sydney on the performance of Hereford steers grazing dried-off Mitchell grass pasture with and without supplements.

Groups of steers received either 3 lb. lucerne hay, 8-11 lb. of grain plus 2 lb. lucerne hay, or 3 lb. kubettes (30 per cent. crude protein) per head per day. The results provided data on which future work can be based.

(*f*) *Vitamin A Requirements.*—Plasma samples were collected regularly from cattle in central Queensland and from others in the coastal region of Queensland. Analyses of these samples are accumulating valuable information on the vitamin A status of grazing cattle.

(*g*) *The use of Antipyrine to Measure Body Water.*—The technique of using antipyriue to estimate body water *in vivo* has been applied to cattle. The study has included an investigation of techniques with repeated assays on the same animals in order to establish the reliability of the technique. The results obtained are being analysed statistically.

(II.) Investigations concerned with beef production at other Divisional centres are listed below.

(*a*) *Environmental Control of Coat Changes in Cattle (University of Queensland).*—As reported previously the light environment exercises an important influence on the seasonal coat changes in cattle. The experiment, with polled Shorthorns, has continued and the coat changes in the two groups have now been followed throughout the year. In addition, observations have been made on heat tolerance in relation to coat type.

By keeping the experimental group on an opposite lighting trend to that of the controls, coat type has been maintained in an opposite state in the two groups. While the controls were in long woolly coats during June and July, the experimental groups were short-coated, smooth, and shining; and at the end of the experiment in December, when the controls had assumed the normal summer-coated state the experimental animals were in deep, curly, winter coats. The experimental animals shed their coats during autumn, the controls during spring.

In heat tolerance tests at 105° F. dry bulb and 92° F. wet bulb in December and June, the groups then in short-coat had n 12 point superiority in heat tolerance coefficient* over the group which carried a deep coat at that time. Following the December test the cattle of both groups were clipped and again submitted to test. The heat tolerance of the two groups was then similar.

(*b*) *Heat Regulation in Cattle (Sheep Biology Laboratory).*—Experiments have shown that the apocrine glands in the skin of cattle have a heat regulatory function. Under a stereomicroscope sweat droplets could be observed forming at the openings of the sweat-gland ducts in response to intradermal injections of adrenaline and during exposture to hot conditions. The sweat spots could be stained macroscopically and prints showing the location of the spots were obtained with bromothymol blue papers pressed on to the skin surface. Quantitative measurements indicate that the evaporation of sweat is the main source of heat loss in hot environments. Electrophoretic analyses of cattle sweat indicate the presence of the main serum proteins and three other proteins in addition. The total protein content of sweat was found to vary from 0.4 to 2.0 per cent.

(*c*) *Adaptation to a Tropical Environment (Rockhampton Laboratory).*—Following establishment of this laboratory, studies have been commenced to define differences between tropical and European breeds of cattle. The work is being done on selected groups of cattle maintained on the National Cattle Breeding Station, "Belmont", Rockhampton. There are marked differences between Zebu-cross and British breeds in terms of thermoregulation (respiration rate, skin, hair, and rectal temperatures). The low skin temperature of the Zebu is particularly notable. Of great interest too are the appreciable differences between individual animals of the British breeds, e.g. mean respiration rate may be two and a half times as great in one animal as in another.

(*d*) *Seasonal Variation in Liveweight of Cattle (Regional Pastoral Laboratory, Armidale).*—The liveweights of New England bred Hereford cows and their progeny have been recorded at monthly intervals. It has been found that only during the spring, summer, and autumn periods will native pastures support the growth of cattle. By the end of April grown cattle and weaners commence to lose condition and require supplementary feeding to prevent further loss in liveweight during the winter.

* Heat tolerance coefficient = [100—10 (Rectal temperature—101)], the temperatures being expressed in ° F.

8. Genetics of Cattle.

(Animal Genetics Section and Division of Animal Health and Production.)

(*a*) *Division of Animal Health and Production.*—The breeding trials at "Belmont" are proceeding according to plan although the 1954 mating season had to be lengthened because of floods, and the subsequent calving extended into 1955. All experimental cattle were weighed at monthly intervals and complete growth-rate records of all calves have been secured.

(i) *Crossbreeding.*—The requirements for this experiment were twelve groups of cows, with fifteen Herefords and fifteen Shorthorns in each group, and four breeds of bulls—Hereford, Shorthorn, Africander, and Zebu—using three bulls of each breed to cover the twelve families of cows. It was desirable to equate each breeding group according to the reproduction history of the cows and this was done on the basis of the breeding records for 1953 and 1954. Bulls for the twelve groups were selected at random and the allocation of paddocks was also made at random. Mating commenced on 21st January and terminated in March. The breeding groups were rotated through the twelve paddocks in an endeavour to reduce the effects of variable pasture conditions.

(ii) *Northern-bred–Southern-bred Trial.* — 1955 matings in this trial also occurred from late January to March. The northern-bred group of 29 cows mated with Bull H4 and the southern-bred group of 28 cows mated with Bull H6 were managed in the same way as the groups in the cross-breeding experiment.

(iii) *Zebu-cross Breeding.*—Calving in this group continued until March and consequently the bull was not introduced until 7th April. Thirty Zebu-cross weaners formed the 1955 group. The two available Zebu bulls were mated with the females alternately for weekly periods.

(iv) *Experimental Calving* 1954.—Of the 360 cows mated in the cross-breeding project, four Herefords and eleven Shorthorns were lost during the season mainly from lantana poisoning. Calving continued from 20th October, 1954, until 28th January, 1955; 214 calves were born, representing 62.3 per cent. from cows mustered at calving.

Calving in the northern-bred–southern-bred trial was satisfactory; 23 calves were dropped in the northern-bred group (77 per cent.) and 23 (79 per cent.) in the southern-bred group.

In the Zebu-cross herd only seventeen calves were obtained from 29 cows and of these fourteen have survived. The calves contain 75 per cent. or more of Zebu blood and are very attractive.

9. Sweat Glands in Cattle.

(Animal Genetics Section.)

Examination of cattle skin corroborates the finding of Dowling and Ferguson that cattle sweat and that Zebus do so to a greater extent than British breeds. Sweat glands of British breeds have one-quarter the volume of Zebu glands, and also are less numerous. Zebu sweat glands seen in cross-section completely fill the area of the section if it is cut at the level at which the glands lie. In British breeds more than half the tissue is other than sweat glands at the same level. A rapid method of preparing skin for examination has been worked out.

IX. ENTOMOLOGY.

1. General.

Throughout the agricultural, pastoral, and horticultural industries, Australia in common with most parts of the world suffers enormous losses from the depredations of insects. As seed, as growing crop, or as harvested food the products of the soil are continually subject to damage by insects of many thousands of species. Before a campaign against any insect can be launched with reasonable hope of success, the life history and habits of the particular species must be thoroughly investigated and understood. The Organization's investigations involving the biology and control of insect pests, the biological control of weeds, and other aspects of entomology are mainly carried out by the Division of Entomology, with head-quarters in Canberra. Collaborative work is, however, undertaken by the Division on special problems in conjunction with other laboratories. Research on insects affecting animals is done in co-operation with the Division of Animal Health and Production and is reported in Chapter VIII.; the Division plays a part in the investigations on the virus diseases of rabbits being studied by the Wildlife Survey Section (*see* Chapter X., Section 2). The Division co-operates with the Division of Forest Products in the study of pests of timber (*see* Section 12 of this Chapter, and Chapter XIV., Section 6 (*h*)).

Division of Entomology.—Several new investigations have been commenced during the current year as the result of the appointment in the last fifteen months of six new officers. These are working in the fields of sensory physiology, surface chemistry of insect cuticle, insect tissue culture, grasshopper ecology and biological control of aphids, wax scales, and ragwort. Work on population dynamics published last year has created world interest. Theoretical and laboratory studies are continuing, and the field studies initiated two years ago are beginning to lead to the accumulation of valuable results.

The Division's work on insect physiology is also attracting a great deal of attention in overseas countries which are attaching a great deal of importance to this aspect of our work.

Another important part of the Division's fundamental work is insect taxonomy. Taxonomic work has never been regarded as a primary function of this Division, but with so many of its officers engaged in ecological studies and biological control, it has become increasingly obvious that we cannot make satisfactory progress without adequate taxonomic studies.

The eradication campaign against the Argentine ant in Sydney is still proceeding. In spite of excellent control in some areas and apparent eradication in others, the discovery of new areas of infestation will necessitate at least two further years' work.

Research on cattle tick control continues to give very encouraging results. Correct timing of dipping schedules with or without appropriate "spelling" of pastures should enable the tick problem to be reduced to negligible proportions over much of Queensland.

Work has commenced on a much-required, air-conditioned brick insectary which was planned many years ago. In Western Australia, the Division's officers engaged in research on the red-legged earth mite and the lucerne flea have moved into the recently constructed Western Australian Regional Laboratory. The Division is grateful to the Institute of Agriculture, Nedlands, for providing accommodation for many years.

The New South Wales University of Technology has the co-operation of the Division in work on the formulation of cattle dips, the chemistry of ants, and the surface chemistry of insect cuticular lipoids. The Division continues to co-operate with the Australian National University and the Wildlife Survey Section in experiments on the mechanism of insect transmission of animal viruses.

Officers of the Division assisted the New South Wales Forestry Commission in two operations against the phasmid *Didymuria violescens* which is defoliating valuable hardwood stands in Bago State Forest. Ground spraying experiments were carried out in the spring, and the area was sprayed from the air in the summer. Co-operative work with the Australian Forestry School has also been done in an attempt to find means of controlling ants which affect the germination of seeds in the forest.

2. Insect Physiology and Toxicology.

(Division of Entomology.)

(*a*) *Digestion of Wool by Insects.*—Further attention has been paid to the characteristic factor in which wool-digesting insects differ from other animals, namely, the possession of highly-reducing midgut digestive juices. These reducing conditions disrupt the resistant disulphide bonds of keratin, which can then be degraded by proteolytic enzymes. Various systems which may be involved in maintaining the reducing conditions are being examined. An enzyme such as cystine reductase has not yet been demonstrated in larvae of the clothes moth *Tineola;* however, a preliminary examination was made of the possible reduction mechanism utilizing free cysteine.

Considerable improvement has been made in the preparation of active enzyme extracts from insects. A very active proteinase can be prepared from blowfly excreta. Fatty materials which are very troublesome in *Tineola* extracts can be eliminated by first drying the larvae over phosphorus pentoxide in a vacuum and then extracting with ether to produce an easily extractable powder. Some purification without much loss of activity can be obtained by cold dialysis of extracts.

(*b*) *Histochemistry of the Digestive Tract.*—Attention has been turned during the year to the hindgut of blowfly larvae. This has proved histochemically and histologically to be a far more complex organ than hitherto believed. The hindgut is divided into short anterior and posterior regions (which function principally as sphincters) and a long central region. The most unusual feature is that the central hindgut is composed of three functionally different cell types, each forming a longitudinal band. Pronounced differences are found between these cells in their content of ammonia, barium, potassium, acid phosphatase, dehydrogenases, and acetyl esterase. It has been shown that certain cells in the hindgut epithelium take up ammonia directly from the haemolymph. Much of the ammonia appears to be eliminated as bicarbonate.

(*c*) *Insect Muscle Biochemistry.*—Studies this year have been concerned with essential differences between the reactions of the actomyosin gel and the actomyosin sol. As a working hypothesis it was assumed that the reactions of the gel (ATP-ase activated by magnesium, synaeresis in the presence of ATP) could be considered to be a model of muscular contraction, whereas the reactions of the sol (ATP-ase activated by calcium, dissociation in the presence of ATP) could not. Most of the detailed work on the energetics of the actomyosin-ATP interaction has been done with the sol, and this information has been used in establishing and testing theories of muscular contraction. If it could prove possible to obtain accurate data on the kinetics of the ATP-ase in the gel phase such information could be placed on a much sounder basis.

As a preliminary to this work it was necessary to trace carefully the influence on the ATP-ase of changes in ionic strength, hydrogen ion concentration, and

the activating effects of calcium or magnesium. This has been done with both rabbit and insect actomyosins. Some determinations of thermodynamic constants have been made with rabbit actomyosin. Considerable difficulty has been encountered in the kinetic studies, owing partly to the insoluble state of the enzyme and partly to the difficulty of measuring the extremely small amounts of phosphate evolved by the enzyme at low substrate concentrations. Radical refinements of the experimental technique have been necessary, but this has now yielded some kinetic data of adequate reliability.

(*d*) *Chitin-protein Associations in Insect Cuticles.*—The adsorption of a water-soluble cuticular protein to chitin has been studied. The adsorption is dependent upon pH, decreasing rapidly as the pH increases from the region of the isoelectric point of the protein. Increase in salt concentration decreases adsorption, but the adsorption appears to be little influenced by changes in temperature. Tyrosine-rich protein fractions are preferentially adsorbed. The adsorption is partly irreversible and an increase to pH 9 is necessary before all the adsorbed protein can be removed. It is concluded that there is only a weak bonding between the chitin and the water-soluble cuticular protein.

(*e*) *Precursors of Cuticular Components.*—Further work has been carried out on the free amino acids and polyphenols of insect haemolymph and the study has been extended to an investigation of the composition of the proteins in the haemolymph. Qualitatively there appears to be little difference in the composition of the proteins from larval, prepupal, and early pupal bloods.

(*f*) *Frequency of Copulation in* Lucilia cuprina.—Mated females of the Australian sheep blowfly *Lucilia cuprina* fairly successfully resist further attempts at copulation. When virgin females are caged with an equal number of males all the females mate within the first half hour. When this is repeated using mated females only very few matings occur and these only in flies which have not mated for about eight days. Whether or not the mated females have been allowed to lay eggs is of little or no importance. The frequency of mating is not limited by the males, which will mate with as many as three females in an hour. It is concluded that females in the field would as a general rule mate only once.

(*g*) *The Function of the Fenestrae in the Cockroach* Periplaneta americana.—A technique was devised for the removal of these organs. Late stage nymphs were operated on and the organs completely removed. When these individuals moulted to adults their heads showed no scars and were normal except for the absence of the fenestrae.

(*h*) *Nutrition and Reproduction in* Lucilia cuprina.—The only amino acids detected in the honeydew of coccids living on eucalypts were alanine, methionine, and tyrosine. These are insufficient to permit the Australian sheep blowfly *Lucilia cuprina* to mature eggs when it is offered coccid honeydew as the only source of protein.

Analysis of the crop and gut contents of wild *L. cuprina* in spring and autumn suggests that sheep droppings and coccid honeydew are by far the most important sources of food available for wild *L. cuprina* in certain areas.

Further investigations of the distribution of carbohydrases present in *L. cuprina* showed the crop to be an important site of break-down of carbohydrates. The presence of a β-fructosidase in the gut has been established. Fructomaltose, an oligosaccharide present in coccid honeydew and reported in the excreta of another blowfly, has now been found in the excreta of *L. cuprina*. Investigations are in progress to determine whether this oligosaccharide is synthesized by the fly or is the result of the action of microorganisms on sucrose.

3. Insects and Viruses.

(Division of Entomology.)

(*a*) *Insect Tissue Culture.*—Many problems of insects and viruses could be tackled if cultures of insect tissues were available. A number of attempts have been made to do this in the past, but in no instance has it proved possible to maintain insect tissues in repeated subcultures. A start has been made to examine the many physical, chemical, and nutritional problems involved in insect tissue growth, and tissue survival for 27 days has been attained.

(*b*) *Leafhopper-borne Diseases of Plants.*—Work has begun on the details of transmission of a virus disease of maize known in Queensland as wallaby ear disease. The disease has been transmitted by the leafhopper *Cicadulina bipunctella* to a number of monocotyledenous plants on which it has not hitherto been recorded. Furthermore the virus is transmitted by the leafhopper to its progeny through the egg; this is only the second report of this phenomenon among a number of viruses transmitted by leafhoppers of the subfamily Deltocephalinae. The concept of a phytopathogenic virus being so closely adapted to its insect vector is of considerable biological interest and the matter is being investigated further. A start has been made to obtain a colony of insects free of virus.

(*c*) *Leafhopper-borne "Yellows" Viruses.*—For some years work has been in progress on the leafhopper vector of tomato big bud, lucerne witches' broom, and related viruses. Two further diseases, both of considerable economic significance, are potato purple top wilt and "little leaf" of subtropical pasture legumes. During the year *Orosius argentatus* Evans has been found to be the vector of both diseases, which are thought to be caused by strains of the big bud-witches' broom complex.

(*d*) *Myxomatosis.*—In further co-operative work with Professor Fenner of the Australian National University emphasis has been directed towards assessing the epidemiological potential of different strains and vectors of the virus.

It has been found that *Anopheles annulipes* is a more effective vector than *Aedes aegypti*, but that it too carries the virus mechanically. An infectious *A. aegypti* that bites a rabbit carrying a high titre of antibody is unchanged in its subsequent ability to transmit the disease. Also, if Murray Valley encephalitis is transmitted to a rabbit simultaneously by the same mosquito transmitting myxomatosis the course of the latter disease is unaltered.

Finally, because the hypothesis has been put forward that attenuation of the virus occurs within the mosquito vector, a strain has been maintained alternately in mosquitoes for two weeks and then in rabbits for one week. The strain has so far been thus passed through six such passages without altering in any measurable way.

4. Population Dynamics.

(Division of Entomology.)

(*a*) *Theoretical and Laboratory Studies.*—Previously all population studies with *Lucilia cuprina* were made under constant conditions, including the provision of food at a constant rate. During the past year the effects of a periodically fluctuating environment upon *Lucilia* populations were studied. The food supply was progressively increased and decreased from day to day so that when plotted it formed a sinuate curve. In each of a series of culture cages the period of fluctuation of the food supply was different. It was found that the population density oscillations due to competition effects, which have a natural period under constant conditions, strongly tended to have impressed upon them the period of external fluctuation, that is, of the food supply. But if the period of external fluctuation

greatly exceeded or was much shorter than the natural period of the oscillations due to competition, a harmonic relationship between the two cycles of change was established. In addition, the violence of change in density was much greater than that which could be accounted for by the change of food alone. That is to say, the violence of oscillation in population density was dominantly due to competition effects.

Examination of the mechanism of density-induced reaction in the *Lucilia* experiments has shown that populations can readily adjust themselves to stresses whether these are due to changes in the environment or in the properties of the species. It has become clear that such compensatory reaction to stresses is an important part of the mechanism of natural selection. Selection itself merely preferentially preserves individuals possessing advantages, but the removal of those lacking advantages is not a passive resultant of selection, as is commonly assumed, but is an active process depending upon density-induced reaction. Further consideration has shown that the direct product of natural selection is not adaptation, in the sense of precise fitting of the environment, but improved defence against environmental hazards which fits the species to withstand even greater stresses than those to which it is exposed during selection.

(*b*) *Field Studies.*—This year's work has consisted of systematic broad-scale field studies on selected species of Psyllidae, three of which are very abundant in parts of the Canberra district where they are causing severe damage and even death to eucalypts.

The initial causes of these localized outbreaks have still to be ascertained, but it seems probable that their persistence is due to secondary entomophagous parasites. Evidence suggests that population limitation of these psyllids is normally due primarily to encyrtid parasites. These parasites are themselves attacked by secondary encyrtid parasites. When psyllid numbers are low, the secondary parasites either attack a variable, but generally rather low, proportion of primaries, or ignore them altogether. However, when the psyllids become fairly numerous, the rate at which their primary parasites are attacked by secondaries increases. In the areas of psyllid outbreak 75 per cent. or more of the primary parasites on the average are destroyed each generation by secondaries. As these are not the only cause of mortality to primary parasites, few survive to attack the next generation of psyllids.

In these circumstances psyllid numbers, in spite of checks due to other factors, frequently increase to the limit set by the available food and favorable space.

5. Locusts and Grasshoppers.

(Division of Entomolgy.)

(*a*) *Locusts.*—The outbreak of the Australian plague locust continued in New South Wales during 1954-55. In the Bogan-Macquarie outbreak area, where continuous field investigations are in progress, swarms were present throughout the season. The usual easterly emigration from the outbreak area took place in each of the three generations, but in the vicinity of Trangie the population was kept replenished by loose swarms moving from further west. Parasitism by dipterous larvae was heavy, especially in the spring generation of adults. Earlier studies indicate that weather conditions such as those experienced in the autumn of 1955 may be expected to reduce the locust population greatly. On the other hand, rain and floods in the outbreak areas of the far west of New South Wales, Queensland, and perhaps South Australia have released a fresh outbreak which has already involved three States.

The continuous presence of migrating swarms in the Bogan-Macquarie outbreak area once more interfered with the work of testing the effect of the shrub-planting treatment of selected outbreak centres as a means of reducing locust multiplication. Nevertheless this work was continued, and, in spite of the disturbing influence of migration, the results continued to suggest that the planting treatment had produced an environment less favorable to the locust. It is hoped that in the coming season swarms will be absent, so that the reaction of the resident population to the treatments may be assessed without the complication of migration.

Following the approval by the Agricultural Council of proposals for a trial control campaign of a new type to be directed against the Australian plague locust at an appropriate time in the future, preliminary steps have been taken, in co-operation with the States affected, in the planning of this campaign. The plan envisages an intensive attack against the early swarms of an outbreak while these are still located in or near the outbreak areas.

In the autumn of 1955 a reconnaissance survey of the locusts and grasshoppers of the Northern Territory was made along the road from Alice Springs to Darwin.

(*b*) *Solitary Grasshoppers.*—A preliminary survey of the grasshoppers in the Australian Capital Territory and adjacent parts of New South Wales during the summer of 1954-55 showed that the two most abundant species were *Phaulacridium vittatum* and *Austroicetes pusilla*. Both species attain their maximum abundance in permanently and temporarily grazed pastures. A method of capturing, marking, releasing, and recapturing adult grasshoppers showed that *Phaulacridium* was sedentary and so this method could be used satisfactorily for determining its density in pastures.

6. Pasture Cockchafers.

(Division of Entomology.)

(*a*) *The Black Beetle* (Heteronychus sanctaehelenae).—Following initial surveys of affected districts of the New South Wales coast, regular observations were made in a number of selected pastures from Grafton to Nowra. Samples were taken in connexion with studies on the life cycle, distribution, and population density of the larvae and adults.

A very severe drop in beetle numbers was recorded during the winter of 1954, when this stage suffered mortality from bacterial diseases. This drop occurred throughout the range of the species in New South Wales and instances of severe damage to crops or pastures were quite rare in the summer of 1954-55. It appears that natural control of numbers is effected by various bacterial and fungal diseases and that insect parasites are comparatively insignificant in their effects.

Swarming flights of the beetle stage occur only under very humid hot conditions. In dry localities (e.g. Adelaide, Perth, and parts of South Africa, to which the insect is native) the beetles do not fly, but walk slowly over the surface. A number of cheap and effective control methods are available for use in such circumstances. In more humid regions, e.g. the New South Wales coast, especially the central and northern districts, swarming flights occur very frequently and crop protection is both difficult and extremely costly.

(*b*) *The Pruinose Scarab* (Sericesthis pruinosa).—This species, well known as a pest of lawns in coastal localities in south-eastern Australia, was first reported in Canberra in 1949. It is now widespread throughout the southern half of the city, and in the present autumn has caused severe damage.

7. Pasture Caterpillars.

(Division of Entomology.)

Investigations were resumed during the year on the identity, distribution, and ecology of the larvae and adults of a series of cutworm and armyworm pests of pastures and field crops. By studying the types of most of these species in the British Museum (Natural History) and the Paris Museum, several errors in nomenclature and identity that have persisted in the Australian literature for many years have now been corrected. All of the Australian pest species hitherto considered to have been accidentally introduced into this country are now shown to occur here naturally. Many are confined to Australia, whereas others of particular importance in the tropical and sub-tropical areas have a distribution through the East Indies to northern Australia.

The impossibility of identifying the larval and pupal stages of these pests has previously been a serious handicap in studies of their distribution and ecology. Series of larvae and pupae have now been reared from eggs laid by accurately identified adults of most of the species and keys for their identification are in preparation.

Observations on the spring migration of *Agrotis infusa* adults were continued and an experimental study of factors responsible for the aestivation of these moths at high altitudes in southern Australia has been resumed.

8. Red-legged Earth Mite and Lucerne Flea.

(Division of Entomology.)

(*a*) *Insecticide Experiments.* — At Nedlands, Western Australia, a number of new insecticides were given preliminary tests against the red-legged earth mite, and endrin and "Dilan" were selected for field trial.

Two large-scale experiments have given interesting results. At Meckering, Western Australia, it was shown that the dosage of parathion could be reduced to ¼ oz. per acre and still give almost complete control of the lucerne flea. Results previously reported for DDT and dieldrin were confirmed. Lindane at 1.1 and 2.3 oz. per acre gave a good control of the earth mite, but was not as effective as the DDT treatment. This insecticide had no toxic effect on the lucerne flea. The predatory bdellid mites were virtually eliminated by DDT, but were not affected by parathion, lindane, or dieldrin. At Grass Valley, Western Australia, malathion and chlorthion (which are said to be relatively non-toxic to the higher animals) proved highly successful against the lucerne flea at dosages from ½ to 1 oz. per acre. The former also achieved a fairly satisfactory control of the earth mite.

(*b*) *Population Studies.*—Observations have been continued on two areas set aside for a study of the changes in the population levels of the red-legged earth mite, lucerne flea, and bdellid mite in pastures. At Walebing, Western Australia, although drought restricted observations to a period of less than three months in 1954, the population contours for the lucerne flea changed in a reverse direction to that of 1953. At Waroona the lucerne flea population remained at a very low level, being greatly surpassed by that of the predatory bdellid mite. Changes in the distribution of the earth mite population at Waroona were again marked, but the pattern was different. At Walebing there was virtually no change throughout the two years of observation.

(*c*) *Effect of Earth Mite on Pasture Production.* —An experiment designed to determine the effect of attack by the red-legged earth mite on the yield and composition of a subterranean clover pasture has now been completed and the results over a period of four years are being analysed. Elimination of the mite resulted in an overall average increase of 15 per cent. (1.4 cwt. dry matter per acre) in total yield of early season (June-July) growth and 11 per cent. (2.7 cwt. per acre) in total yield of late season (October) growth. In both early and late season growth there was a substantial increase in the yield of subterranean clover and to a lesser extent in miscellaneous grasses, a slight increase in *Erodium,* and a distinct decrease in cape-weed.

(*d*) *Physiological Studies.*—The influence of temperature on the development of the aestivating aggs of the red-legged earth mite has been studied in further experiments. A preliminary study has shown that, given adequate moisture, the ability of these eggs to utilize periods when temperatures are suitable for development is dependent upon the nature of their previous exposure in a moist state to temperatures above the developmental maximum (about 21° C.). Thus in the field when moisture becomes adequate, development during the favorable temperatures at night will take place only when temperatures during the day are either below this maximum or above it for only short periods.

(*e*) *Bdellid Mite Distribution.* — A preliminary identification of the bdellid mites collected over a wide area of the south-west of Western Australia has indicated that at least ten species are present, some having a wide and others a restricted distribution.

9. Cattle Tick.

(Division of Entomology.)

This work is reported in Chapter VIII., Section 5.

10. Insect Pests of Stored Products.

(Division of Entomology.)

Investigations into air-tight grain storage have continued and a study of the effects of this method on the small strain of the rice weevil, *Calandra oryzae,* has been completed. It has been shown that, in general, this species responds in the same way as the grain weevil, *Calandra granaria,* but there was some indication that very young larvae pass through a critical stage during which they are very susceptible to combinations of oxygen and carbon dioxide only a few per cent. different from those occurring in normal air. If this can be confirmed it will mean that long-term storage of grain infested by this species could be successfully carried out in silos having a much lower standard of sealing than that previously considered necessary.

The erection of an experimental 1,000-bushel steel silo has been completed. It has been rendered as air-tight as possible by treatment of all joints and seams with a sprayable plastic preparation. In order to follow changes in the temperature and moisture of the grain and changes in the composition of the intergranular air, special equipment has had to be built. As the silo must remain air-tight during the course of an experiment, distance measuring techniques have been employed. A network of sampling points has been installed, each point carrying a thermocouple and a fine sampling tube for the extraction of gas samples.

11. Biological Control.

(Division of Entomology.)

(*a*) *Weed Problems.*—(i) *St. John's Wort* (Hypericum perforatum).—The laboratory colony of the cecidomyid gall-fly *Zeuxidiplosis giardi* has been maintained, and during the year further liberations were made in New South Wales and Victoria. Of the

two original liberations made during 1953, one appears to have been unsuccessful, while the other at Tuena has made little progress.

(ii) *Ragwort* (Senecio jacobaea).—A survey has been made of the ragwort infestations in the Gippsland and Otway areas of Victoria. Preparations have been made to import *Euchelia (Tyria) jacobaea* from England, and from the Mediterranean region.

(iii) *Lantana* (Lantana camara).—As a result of the Central American exploratory work, a number of insect enemies of lantana are now available in Hawaii for introduction into Australia.

(*b*) *Insect Problems.*—(i) *Cabbage Moth* (Plutella maculipennis).—The European larval parasite *Apanteles plutellae*, although still being liberated in selected localities, has been repeatedly recovered and is certainly established. The introduced pupal parasite, *Diadromus collaris*, is becoming more abundant and widespread. Field parasitism by the complex of introduced parasites remains at a very high level, *Horogenes cerophaga* being especially numerous. The evidence that *Plutella* has declined in abundance continues to accumulate.

(ii) *Cabbage White Butterfly* (Pieris rapae).—The liberation of introduced parasites of this pest has ceased for the time being. *Apanteles glomeratus* and *Pteromalus puparum* are evidently generally distributed in the cabbage-growing areas of the Commonwealth and a very high percentage parasitism of the host occurs. *Apanteles rubecula* is established, but apparently it is not yet as abundant as the other two species.

(iii) *Green Vegetable Bug* (Nezara viridula).—The egg parasites *Microphanurus basalis* (West Indian strain) and *Ooencyrtus submetallicus* continued to be cultured at Canberra and liberated in the field. Neither of them successfully overwintered out of doors in Canberra.

So far, no recoveries have been made of *O. submetallicus*, nor was *Trichopoda pennipes* (an American parasite released several years ago) recovered during the year. Field studies have disclosed the presence of certain native primary egg-parasites of *Nezera*, and also of a hyperparasite of the established egg-parasite, *M. basalis*.

(iv) *Queensland Fruit Fly* (Strumeta tryoni).—The main emphasis of work in the past year has been on collecting fruit samples from situations where insecticides are not employed and on rearing out the contained insects. The objective has been to obtain data on the existing relationships between *S. tryoni* and its insect parasites, in order to assist in future evaluation of the effects on Queensland fruit fly populations of the introduction into Australia of foreign fruit-fly parasites. No imported parasites have been released so far in the present programme.

Populations of *S. tryoni* in the Sydney metropolitan area, and also at Coff's Harbour and Tamworth, New South Wales, seemed to be virtually unaffected by endoparasitic insects. *Opius tryoni* was the main parasite obtained in all three districts, only one other record being obtained in Sydney, and a few specimens from the *O. persulcatus* group in Coff's Harbour.

Trapping of adult fruit flies was carried out through the year at selected locations in the Sydney area. The great increase in fruit-fly activity in 1954-55 compared with previous years, reported generally in New South Wales, was reflected in the catches in these traps, which also showed a well-defined period of activity between November and May.

(v) *Wax Scales* (Ceroplastes *spp.*).—The citrus areas of coastal New South Wales and Queensland have been surveyed in order to assess the degree of infestation and to discover any native parasites attacking these scales. Arrangements have been made to import from Japan a small consignment of a wasp parasitic on the pink wax scale (*C. rubens*). Particular attention is also being paid to the white wax scale (*C. destructor*).

(vi) *Aphid Parasite and Predator Studies.*—Numerous species of Aphidiinae (Ichneumonoidea) and Aphelinidae (Chalcidoidea) have been bred out from aphids, but their efficacy is often reduced by the action of hyperparasites. This is especially true in the case of *Brevicoryne brassicae* which may be hyperparasitized to the extent of 85 per cent.

12. Termites and Other Wood-destroying Insects.

(Division of Entomology.)

(*a*) *Termite Investigations.*—Materials submitted to tests in 579 standard laboratory termite colonies included Australian commercial timbers, local and imported hardboards, and a wide range of plastics such as polyvinyl chloride, polythene, polystyrene, and cellulose acetate-butyrate. In addition to examining the relative resistance of the plastics themselves, the effects of different plasticizers, fillers, pigments, &c., is being studied, to determine the combinations of additives which produce the most resistant end product. Work is also in progress in an effort to characterize the compound or compounds present in the wood of black bean (*Castanospermum australe*) which make this timber so highly resistant to termite attack.

Additional field tests of preservative treatments were installed around mound colonies of *Nasutitermes exitiosus* and *Coptotermes lacteus* during the past twelve months. These included tests of the efficacy and permanence of surface treatments with such materials as creosote, sodium arsenite, chlordane, aldrin, dieldrin, and pentachlorphenol.

Additional soil-poisoning tests were installed around mound colonies of *N. exitiosus* and *C. lacteus*, and in the Riverina against completely subterranean species such as *Coptotermes frenchi*, *Heterotermes ferox*, and *Microcerotermes* sp., using lindane, aldrin, tetrachlorobenzene, chlordane, and dieldrin.

(*b*) Lyctus *Investigations.*—Investigation of the nutritional requirements of *Lyctus* larvae is now centred on their ability to utilize various sterols and steroid compounds. Results so far indicate that the larvae are able to bring about bond shifts, hydrolyses, and dehalogenations to convert the derivatives to the parent sterols which are then metabolized.

13. Ant Investigations.

(Division of Entomology.)

(*a*) *Meat Ant.*—Past work has shown that the successful control of colonies of the meat ant (*Iridomyrmex detectus*) is usually followed by the occupation of the treated nest site by ants from neighbouring colonies.

An experiment has been carried out near Canberra to compare sprays and dusts of several insecticides for meat ant control.

(*b*) *Argentine Ant.*—The last of a series of experiments in co-operation with the State Department of Agriculture to study the effectiveness of dieldrin in Western Australia has been completed. At Shenton Park no Argentine ants were found in the houses treated with sprays containing 0.5 per cent. or 0.375 per cent. dieldrin, while 0.25 per cent. dieldrin gave very good control. These results were obtained in time to be of use for the eradication campaign in Western Australia and it was decided to use 0.5 per cent. dieldrin for this work.

The eradication campaign in progress in Sydney in co-operation with the New South Wales Department of Agriculture and local government bodies was continued during the year. A careful examination of all areas treated up to the end of 1954 was made in February-April, 1955, and 32 of the 68 areas were

free of ants while most others contained very few ants. It was estimated that the actual space occupied by the Argentine ants in the area treated (almost 3 square miles) was less than 50 acres. Sixteen additional infested areas were found late in the year, and fourteen of these, totalling 150 acres, were treated.

Sprays containing 0.75 per cent. dieldrin superseded the 2 per cent. chlordane sprays when stocks of the latter insecticide were exhausted.

In Victoria the experiment to compare sprays containing 0.5 per cent. dieldrin and 2 per cent. chlordane for eradicating Argentine ants from the Melbourne University grounds was examined. Dieldrin proved more effective, only one small colony persisting in the 22 acres treated with it.

(*c*) *Ants Affecting the Germination of Forest Trees.*—Seeds of *Eucalyptus cinerea* sown in October, 1953, after spray treatment of cleared forest areas with 2 per cent. chlordane, did not germinate for nearly a year due to absence of rain. Counts made on the two treated and two untreated plots in June, 1955, showed that 172 seedlings were growing on the treated plots while no seedlings were found on the untreated plots.

14. Insecticide Investigations.

(Division of Entomology.)

The study of factors influencing the susceptibility of insects to insecticides has been continued, using houseflies as the principal test insects. In an attempt to determine whether susceptibility and pre-adult development rate are linked and inherited, as indicated in earlier work, three substrains from the Canberra laboratory strain have been selected for rate of development and tested for susceptibility after a number of generations. Although little difference from the unselected parent stock was found in the fast (with respect to rate of development) and intermediate substrains, flies of the slow substrain were found to be up to seventeen times as resistant to DDT.

Observations on the biology of the three substrains have shown that rapid development is an inherited characteristic, and that fewer individuals reach maturity in the slow substrain. The correlation between susceptibility, rate of development, and viability indicates a mechanism by which, in the absence of selection, resistant individuals are maintained in minority in the population, and a stabilizing influence is thus exerted on the susceptibility of the strain. Similar studies are being made on a DDT-resistant field strain from the Roseworthy Agricultural College, South Australia, and on another resistant substrain developed in Canberra.

15. Taxonomy.

(Division of Entomology.)

It is almost universal in Australian entomology for a worker to find that the identity of the species he is studying is open to doubt; in fact, in many instances it has not been described at all. A good example of this is given in the section (this Chapter, Section 7) on pasture caterpillars, where it is reported that taxonomic studies have shown all of the Australian pest species of armyworms and cutworms to be native species, whereas several native species have often been confused previously under the name of a common overseas species.

One of the subjects which was given considerable prominence at the Sixth Commonwealth Entomological Conference in 1954 was the training and supply of taxonomists. This is a serious problem throughout Commonwealth countries and it is not unexpected therefore that in Australia, one of the youngest of all, the position is worse than in most. There are comparatively few active taxonomists in this country. Entomologists in C.S.I.R.O., therefore, are not infrequently obliged to enter the taxonomic field if their investigations are to be of any value. Even in laboratory experimental work there are examples where it has been proved, after the work is statistically analysed and published, that the experimenter was working with a mixture of species, and not one as he snpposed.

To establish the taxonomic status of any insect, it is frequently necessary for a worker to study the whole taxonomic unit, which may be only the genus, or perhaps the family to which it belongs.

References have been made in the appropriate sections to taxonomic work on locusts and grasshoppers, cockchafers, cutworms, armyworms, and Psyllidae. Other major groups which are being studied in the Division are the Diptera to which belong important species of blowflies, and the Chalcidoidea, which includes the most important of the parasitic wasps, cockroaches, termites, and ants. The Ichneumonidae and Braconidae, other important families of parasitic wasps, are being studied by a New Zealand entomologist.

X. WILDLIFE.

1. General.

In every country in the world mammals and birds, both native and introduced, affect primary production and other human activities in a variety of ways. In Australia, what may conveniently be termed wildlife problems range from that of the rabbit, the country's most serious pest, to the mutton bird, on which a small but valuable local industry depends. Kangaroos, possums, and ducks of various species may be pests at various times and in parts of their range, while calling for conservation elsewhere because of their economic value or their importance as game. To deal with wildlife problems that called urgently for solution or merited scientific study for other reasons, the Organization established its Wildlife Survey Section in 1949.

Wildlife Survey Section.—During the first two or three years of the Section's existence its time was virtually monopolized by investigations of the rabbit and its control, and particularly by the virus disease myxomatosis which, after its successful liberation in 1950, has brought annually increasing benefit to the country.

In many of its investigations the Wildlife Survey Section depends materially on collaboration with State Departments, with Universities (particularly the Australian National University), with other branches of the Organization, and with individual landholders. Among the establishments which have collaborated in the work of the Section are: the Western Australian Department of Agriculture, the Vermin and Noxious Weeds Branch of the Victorian Department of Lands and Survey, the Tasmanian Department of Agriculture, and the Victorian Fisheries and Game Department.

The Section has established very close relations with the Antarctic Division of the Department of External Affairs, and has taken on a consultant and advisory role in connexion with the biological research carried out by the Australian National Antarctic Research Expedition.

2. Rabbit Investigations.

(Wildlife Survey Section.)

(*a*) *Myxomatosis.*—Over the greater part of the eastern mainland States there was widespread myxomatosis activity during the 1954-55 season. When the full effect of the summer outbreaks could be assessed, it was found that rabbit numbers were generally as low as they were at the end of the 1952-53 season in which the disease was particularly effective. Some districts, e.g., the New England area of New South Wales, received their first effective regional kill since the disease was liberated in 1950. The extremely

satisfactory disease performance during the past season was clearly indicated by the results of the survey, carried out annually, of three sample areas, each of 100 square miles, in the eastern Riverina. These surveys now provide a four-five year picture of myxomatosis activity and its results, which are found to be closely correlated with the amount and distribution of seasonal rainfall.

As in the previous year, intensive stndies of disease and insect vector activity in carefully selected areas have comprised the major part of the myxomatosis research programme. The main study areas are: (*a*) two sites in Western Victoria, one being in the Mallee, (*b*) three sites in the eastern Riverina representing river frontage, foothills, and plains, (*c*) two sites in typical northern tableland country near Armidale in New South Wales, and (*d*) two sites in the hilly coastal country of southern New South Wales. The data obtained confirm the importance of *Anopheles annulipes* and *Culex annulirostris* as vectors in the inland areas, the former being mainly responsible for spring and autumn epizootics and the latter for outbreaks occurring in summer. An unusual feature of the season was the occurrence of high atmospheric humidities during the summer which resulted in widespread activity on the part of *C. annulirostris,* a species that is normally restricted to the neighbourhood of water.

The vector picture in the coastal and near-coastal country is now known to he more complicated than is that of the inland regions. In the Merricumbene study area, on the Moruya River, six recoveries of the myxoma virus were made during the summer from a total of 871 mosquitoes, i.e., two from *C. annulirostris,* and one each from *A. annulipes, Aedes alboannulatus, A. notoscriptus,* and an undescribed *Aedes* spp. It was observed that peak numbers of mosquitoes (chiefly *A. annulipes*) were found resting in rabbit warrens during periods of prolonged wet weather as well as during periods of extreme dryness. At Colo Vale, the second coastal study area, the reappearance of myxomatosis, after an apparent absence of 22 months, was correlated with an increase in the population of *Aedes alboannulatus,* although this was only one of seven species of mosquitoes and two of sandflies shown to feed on rabbits in the area. In New England observations indicated that *Culex annulirostris* was the main vector in the summer epizootic, but that *Aedes alboannulatus* and *A. vittiger* probably played a part in transmission. As a result of these intensive studies of vector ecology and behaviour in relation to climatology and disease activity, knowledge of the transmission and performance of myxomatosis and their prospects under varying seasonal conditions is now approaching the stage where it can be considered adequate.

Certain characteristics of the disease produced by the French strain of the myxoma virus suggested that it might be more successful than the Australian "standard" strain in competition with attenuated strains that have become prevalent in the field. Two field trials of the French strain were accordingly carried out during the year, in collaboration with the Australian National University, one at Lake Urana in the Riverina Plains and one at Merricumbene. In both cases the French strain failed to gain ground in competition with the local strain. The fate of the French strain was followed in greater detail in the Lake Urana trial, and the results were particularly interesting. The local virus was present in low concentration before inoculations with the French strain were initiated in early November, 1954. By mid-December, 241 inoculated rabbits were released in the area; and the disease became well established and subsquently reached epizootic level. Tests carried out by the Microbiology Department of the Australian National University on virus samples isolated at different stages in the epizootic showed that the French strain (presumably because of the large numbers of inoculated rabbits liberated) at first dominated the local strain; by mid-December recoveries of the French and local strains were made with approximately equal frequency; but from that date onwards the local strain became dominant, and it was the only one recoverable at the end of the outbreak.

The "interference" of one strain of myxomatosis virus by another was studied under laboratory conditions. It was shown that prior inoculation with an attenuated strain protected rabbits from the lethal effect of a virulent one. The evidence indicated that the lesions contained virus of both strains; but on passaging the more virulent strain became dominant, and produced mortality in experimental rabbits on the third passage.

(*b*) *Rabbit Biology and Ecology.*—The analysis of samples taken periodically from rabbit populations (primarily in connexion with the myxomatosis investigations) provided interesting indications on such matters as mean longevity and variation in litter size with age of doe. To get a measure of the "resilience" of a rabbit population, and its power of recovery from mortalities imposed by poisoning and other control measures, more precise information is required on these points, and also on such things as kitten survival under different conditions of population density, and the number of litters borne by the average doe in one breeding season. It was felt that this information could only be obtained satisfactorily from a rabbit population maintained under close and continuous observation, which would permit the history of individual animals to be followed. Accordingly an experiment has been initiated to determine whether rabbit populations can be held and studied in enclosures under conditions that would approximate to those in nature. If this preliminary trial is successful a series of long-term enclosure studies will be initiated.

(*c*) *Rabbit Poisoning.*—Enclosure experiments on the behaviour of rabbits during "free feeding" were continued in Tasmania, with interesting results. Under these conditions, individual rabbits and small social groups develop remarkably stereotyped patterns of movement and feeding, and the problem is to divert them to a new source of food. Exact siting of the furrow in relation to these patterns is all-important. As the aim in poisoning is to get as many rabbits as possible to take some bait, a technique was devised to measure the nightly feeding activity of each individual. The carrot bait was labelled with radio-iodine, which is absorbed into the blood and concentrates in the thyroid. Capture of the rabbits each day, and Geiger counter readings of the stomach and thyroid, revealed the feeding history of each rabbit. Wide individual differences were found, and the final problem is to induce the more timid and less social rabbits to take bait, even where the furrow is well sited.

Details of poisoning technique and choice of materials, already largely understood from the field trials and practical experience of the Tasmanian Department of Agriculture, have been confirmed by the enclosure experiments and by a field trial which accompanied them.

The broad conclusion is that furrow poisoning, using compound "1080", can be a highly effective method, and can achieve high-grade kills at relatively low cost when it is done with understanding.

3. Kangaroo Investigations.

(Wildlife Survey Section.)

The Woodstock Field Station, situated between Port Hedland and Marble Bar is north-western Australia, has now been in operation for a year. Woodstock is typical of the region in which the hill kangaroo or

euro (*Macropus robustus*) constitutes a serious problem. During the first working season, a good deal of time had to be spent on developing techniques for the study of euro biology and behaviour, on an accurate knowledge of which an improved strategy of control must very largely depend.

Euros are largely nocturnal in their habits; and to facilitate the estimation of the numbers of the animals visiting watering places (and the change in numbers following control measures, on which the assessment of the efficacy of these measures must depend) automatic counters have been devised and successfully tested. With a view to capturing animals unharmed for marking, release, and subsequent observation, experiments have been carried out with narcotics. Chloral hydrate, dissolved in water in drinking troughs, was found to be effective and permitted the handling of animals without difficulty. Attempts to stock specially built enclosures for controlled poisoning trials were not successful. Adult euros did not settle down and survive in captivity.

As the control of euros in practice seems likely to depend on poisoning at watering places, a detailed study of the water relations of the animals on Woodstock is being carried out. The main natural drinking places in the Woodstock area are watercourse soaks which the animals scratch out to reach the water-table, which may be some feet below the dry sand surface. The increase in the euros visiting stock waters is expected to be closely correlated with the progressive drying up of the soaks as the season advances.

Transect count methods for estimating population distribution and density are being tested. Monthly samples are being examined to determine whether there is a well-marked breeding season. Observations on the rate of growth, on feeding habits, and on predation by wild dogs and wedge-tailed eagles are being carried out. Preparations are being made for the study, during the next dry season, of the use of salt licks as a basis for poisoning.

4. Mutton Bird Investigations.

(Wildlife Survey Section.)

The joint investigations with the Tasmanian Fauna Board of the economic biology of the mutton bird, *Puffinus tenuirostris*, comprised several periods of field work on the Bass Strait islands. In connexion with these, assistance in personnel was given by the Department of Zoology of the University of Tasmania, and the Australian Museum in Sydney.

On Fisher Island the life history studies are proceeding. Several of the birds banded five years ago as fledglings have returned to the island for the third successive year. These are still non-breeders, thus indicating a fairly long period of immaturity in the species.

The "Lincoln Index" studies, designed to assess the effect of the industry on the mutton bird population, are being continued. To this end, 2,200 birds were banded on the commercial islands before the season opened.

In collaboration with the Institute of Medical and Veterinary Science in Adelaide, investigation was made of a strain of ornithosis (psittacosis) among *Puffinus tenuirostris*. The virus was isolated from an adult bird, and the infection was found to be common among both adults and fledglings.

5. Ibis Investigations.

(Wildlife Survey Section.)

A survey throughout northern New South Wales and southern Queensland gave evidence of a major movement of the straw-necked ibis, *Threskiornis spinicollis*, and the white ibis, *T. molucca*, into eastern coastal regions during winter, and of a return to inland waters in early spring.

At the time when grasshoppers were emerging in the Macquarie Marsh region, a study was made of the feeding relationship between the ibis and these insects. The straw-necked species was found to feed consistently on all stages of grasshoppers, but where plague numbers are present the overall effect must be slight, and the critical point is whether the ibis has an appreciable effect on much sparser numbers and so help to prevent a population from building up.

Aerial surveys proved to be a valuable and economic method of reconnaissance for ibis colonies.

The essential relationship between the breeding of the ibises and the water level in the marshes was again demonstrated. Nesting in the Macquarie Marshes was very limited until after the great floods of late summer started to subside. Very populous colonies of both species were then formed, and the opportunity was taken to band large numbers of fledglings. Some 2,600 young straw-necks and 177 white ibises now carry C.S.I.R.O. bands, which should in time yield information on dispersal and seasonal movements, future breeding places, length of life, and other facts.

6. Bird Banding.

(Wildlife Survey Section.)

In the first year of its operation, the national scheme has enrolled 31 active banders, of whom eighteen are amateur ornithologists. The officer responsible for fauna protection in each State where they operate has co-operated by issuing the appropriate licences.

Members of the Australian National Antarctic Research Expeditions on Heard and Macquarie Islands have banded 2,351 birds, and a further 3,625 have been done in Australia.

7. Wild Ducks.

(Wildlife Survey Section.)

Studies of breeding biology were hampered by the almost complete absence of duck breeding in the region under study—the Murrumbidgee Irrigation Area. For the same reason the results of the banding programme were disappointing, and in future it will be necessary to be more mobile and to band ducks wherever they happen to congregate, rather than to develop permanent banding sites. Extensive breeding did occur in northern New South Wales, following the February floods, and a comparison of the conditions in the two areas will clarify some of the factors affecting breeding.

Little or no damage was caused by ducks to the rice crops in the Murrumbidgee Irrigation Area. It seems clear that ducks are unlikely to be a problem to irrigated rice, except when local conditions attract concentrations of breeding birds, and the juveniles later experience a shortage of food as the swamps dry up.

8. Quokka Studies.

(Wildlife Survey Section.)

Two investigations of the quokka (*Setonyx brachyrus*) are being carried out. A field population study has been undertaken with a view to gaining an understanding of the natural factors governing the population of a type of native animal that is in need of conservation; while the digestion of the quokka is being studied in the laboratory because of the interest attached to the resemblance between the process in this marsupial species and that in the sheep and other ruminants.

The population study is located on Rottnest Island, off Fremantle, Western Australia. Methods of catching, marking, and sampling the animals have been developed; and to date 650 quokkas have been marked and information has been collected on their breeding

season, on the survival of pouch young, juveniles, and adults, on the growth of young, on movements, and on other aspects of behaviour.

A better understanding of the physiology of digestion in *Setonyx* has been obtained by a study of the rate of passage of food through the gut, the digestion of crude fibre, and the nitrogen balance. It was found that the passage of food is very much faster than in ruminant, and that the amount of crude fibre digested is also greater. These findings are of considerable interest as they show that the quokka is not so like the ruminants as was previously thought, and that it takes up a position intermediate between them and non-ruminant herbivores. No "intermediate" type has been investigated hitherto.

XI. UNDERDEVELOPED REGIONS.

1. General.

The normal processes of exploration and pioneer occupation have resulted in the rural settlement of most accessible and easily developed parts of Australia. There are, however, large portions of the continent and the territories which are underdeveloped or only very sparsely occupied, by reason of low rainfall, poor soils, sparse pastures, inadequate water, and great distances from centres of dense population.

It is essential to understand the problems of these areas and where possible to solve them, so that either new developments can take place or the present level of production can be protected from unwise exploitation.

The development of northern Australia in particular has been slow in comparison with that of the southern and eastern States. The Organization's Land Research and Regional Survey Section conducts surveys of Australia's underdeveloped areas in order that their potential may be more accurately assessed.

Whilst the work of the Land Research and Regional Survey Section is thus concerned with the sparsely populated arid and semi-arid regions of the continent, much complementary work is carried out by other divisions of the Organization on the development of low-producing areas in the less isolated regions. The Division of Biochemistry and General Nutrition is investigating problems of plant and animal nutrition on the Coonalpyn Downs in South Australia (*see* Chapter III., Section 11), the Plant and Soils Laboratory is studying the wallum country in eastern Queensland (*see* Chapter III., Section 22), and the Division of Soils is making soil surveys throughout the Commonwealth (*see* Chapter II.). Allied work is also carried out by the Division of Plant Industry on plant and pasture ecology at Trangie, New South Wales, south-eastern Queensland, and elsewhere (*see* Chapter III.).

Land Research and Regional Survey Section.—The Section has its headquarters at Canberra and field stations at Katherine, Northern Territory, Ivanhoe (Kimberley, Western Australia), and Alice Springs, Northern Territory. The Section is concerned with: (1) the survey and mapping of large underdeveloped regions and the primary assessment of land-use potential; (2) research into problems of agricultural and pastoral development in selected portions of those regions; (3) climatological studies; and (4) research into land-use problems of the arid and semi-arid zone of central Australia.

In addition to these specific fields of research, the Section is closely associated by representation on technical committees with experiments with rice-growing and other projects in the Northern Territory and with tropical pasture work in Queensland.

The Officer-in-charge of the Section was Australian delegate to the F.A.O. International Rice Commission's Meeting and Working Party on Fertilizers held in Tokyo, Japan, in October, 1954.

During the year the Section's Director of Field Stations participated in a grasslands survey organized by the South Pacific Commission to investigate the beef cattle potential of the Commission's territories.

The Senior Survey Officer spent seven months in the equatorial, tropical highlands, and monsoonal zones of Africa. The primary objective was to study soils in relation to climate and land use with a view to obtaining information that may be applicable to northern Australia and Australian New Guinea.

Two officers of the Papua-New Guinea survey unit paid a short visit to Dutch New Guinea to observe the approach of the Dutch to some of their basic problems which are essentially the same as those of Australian New Guinea.

2. Regional Surveys.

(Land Research and Regional Survey Section.)

The two regional survey units of the Section continue to operate, one on the mainland of Australia and one in the Territories of Papua and New Guinea. The first unit has been in operation in Northern Australia since 1946 and has completed surveys of the following areas: Katherine-Darwin (27,000 sqnare miles), Barkly (120,000 square miles), Townsville-Bowen (6,000 square miles), Ord-Victoria (70,000 square miles), and Leichhardt-Gilbert (110,000 square miles). The New Guinea unit was established in 1953 and has completed surveys of the Buna-Kokoda area (2,500 square miles) and the Wanigela-Cape Vogel area (600 square miles).

The main function of each unit is to classify and map the lands according to surface characteristics of importance in the determination of land-use potential. The second is to make the best possible assessment of the possibilities of land use, together with the estimates of areas of each type of country mapped. The surveys provide a basis of facts necessary for the formulation of policies concerning land development or conservation.

(*a*) *Australian Mainland Survey Unit.*—(i) *Leichhardt-Gilbert Area.*—Again this year the survey team has been concerned mainly in this area, for which the field work was completed in 1954. During that field season close collaboration was maintained with a member of the Bureau of Agricultural Economics. The final interpretation of the aerial photographs of the area has been completed and maps and reports are being prepared.

The area consists of six main types of country—

The Western hilly area of metamorphic rocks of the Carpentaria complex. This is almost useless for grazing purposes, bnt is an important mining area. The Cloncurry, Mount Isa, and Mount Oxide mining areas are among the best known. Since uranium became an important mineral, there has been a period of intense prospecting activity and several areas are now being tested.

A broad belt of heavy soil country extending from the Gulf of Carpentaria to almost the full width of the southern part of the area. This belt carries treeless Mitchell grass pastures and is extensively used for grazing. The southern part is mainly used in sheep grazing; the northern, cattle grazing.

A north-south belt of flat "sandy forest country" carrying mostly low paperbarks and poor grasses. It is mostly nnoccupied and unused.

A belt of steeply dissected sandstone country of little or no use for grazing, but on which there has been some mining activity.

The eastern highlands country in which palaeozoic rocks of the Etheridge and Broken River Groups are important. Except for the hillier parts grazing is important and a number of mineral fields have been worked.

The basalt country of the eastern highlands, which is an important pastoral area.

(ii) *Georgina Poison Area.*—At the conclusion of the field work in the Leichhardt-Gilbert area several members of the team visited the Georgina Poison Area where they collaborated with the Animal Industry Branch of the Northern Territory Administration in preliminary survey work and feeding trials. The feeding trials further substantiated field evidence of marked differences in toxicity of *Acacia georginae* in different areas. Further survey work is to be undertaken in September-October, 1955.

(iii) *King Edward-Drysdale Area.*—During September, two members of the team and an officer of the Bureau of Agricultural Economics visited this area (previously referred to as North Kimberley Area) to make a botanical, soil, and land classification assessment. Maps and reports of this work are now being prepared.

In April and May, 1955, a botanical collecting trip was made to this area at the conclusion of the wet season.

The best country, which is of only moderate grazing potential, consists of a north-south belt of volcanic country mainly along the Carson and Drysdale Rivers. The remainder of the area is largely of poorer sandstone country. Mapping from aerial photographs is being extended further west to cover the drainage basins of the Charnley and Prince Regent Rivers.

(*b*) *Papua-New Guinea Survey Unit.*—(i) *Buna-Kokoda Area.*—The preparation of the general and specialist reports is proceeding and final maps will be prepared in the near future. The National Mapping Office, Department of Interior, is preparing an accurate base map by the slotted templet method, but the work is difficult owing to the variability of scale and the poor quality of the aerial photographs.

(ii) *Wanigela-Cape Vogel Area.*—This area of approximately 1,600 square miles was surveyed in 1954. Because of the complexity of the rain-forest vegetation, a forest botanist was added to the team of work in association with the systematic botanist and the ecologist. The Government Geologist, Port Moresby, accompanied the unit in the field and carried out the geological and geomorphological parts of the survey programme.

Traverses were made by foot patrols. Transportation of supplies, mail, &c., were facilitated by clearing of the airstrip at the main base, Wanigela, and by the use of a work-boat for transport along the extensive coastline.

The area can be divided into three major types of country: namely, the volcanic region of Cape Nelson, including Mount Victory and Mount Trafalgar; the gently sloping forested flood-plains extending from the foot of the central ranges; the low hilly Cape Vogel area, with extensive areas of anthropic savannah on skeletal soils over Tertiary sediments.

There appear to be good agricultural prospects on limited areas of Mount Victoria volcano and limited possibilities, due to stoniness and poor drainage, on the extensive flood-plains. Some of the grasslands in Cape Vogel on the foothills of Mount Trafalgar may have some potential for grazing. The extensive tall forests on the plains and on Mount Victory appear to have forestry potentialities, but specialized forestry investigations will be necessary to prove their worth.

3. Agricultural Research in North Australia.

(Land Research and Regional Survey Section.)

(*a*) *Katherine Research Station.*—(i) *Crops.*—Weather during the past season has been very satisfactory for plant growth. While total rainfall was only slightly above average, distribution was excellent, and at no time was water shortage a major limiting factor in plant growth. Humidity remained generally high and excessive temperatures did not occur. Harvests have been much more uniform than in recent years, and have attained high levels (sorghum 3,500 lb./acre, peanuts 2,000 lb./acre). Wide fluctuations in the yields of cotton indicate that some factor not yet appreciated is the major determinant of yields. Guar (*Cyamopsis tetragonoloba*) gave excellent vegetative growth, but disappointing yields. Sunflowers developed well in early stages, but termites caused damage and a poor yield resulted.

(ii) *Fertilizers.*—Sorghum and peanuts responded to rock phosphate, but the response was only a fraction of that obtained with superphosphate. Current sorghum experiments show marked residual effects with both rock phosphate and superphosphate.

(iii) *Soil Moisture Studies.*—The very rapid drying out of exposed surface soils has been confirmed. The heaviest rains normally experienced (2 inches in 24 hours) wet bare uncultivated soil to a depth of only a few inches and this wetted layer quickly dries out. In an area of bare land, moisture content below 12 inches has shown little change since the last dry season, in marked contrast to an adjacent grassed area where rainfall has penetrated to a considerable depth and where the amount of stored water has increased greatly throughout the season. Only in periods of persistent rainfall, when the surface soil is frequently rewetted, do seeds have an opportunity to establish themselves in such areas. Cultivation facilitates the deep penetration of water beyond the reach of the surface effects.

Attempts to establish small seeds with the aid of "nurse crops" were a complete failure. Seed germinated readily, but all seedings succumbed, even when seedlings without the benefit of nurse crops survived.

(iv) *Cultivation and Tillage Practices.*—These have given no very marked responses in this almost ideal year. Water conservation through basin listing has again given negative results. Crop rotation sequences have given striking results. Cotton, sorghum, and peanuts all do much better when following a peanut crop than when following either of the others.

(v) *Pests and Diseases.*—There have been no serious pests or diseases. Birds are always a menace to ripening sorghum, but can be kept at bay by gun patrols.

(vi) *Native Pastures.*—Yields have been better than in past seasons, but the grasses matured and dried off long before the rains ceased. *Themeda* is grazed far more heavily than any other species. Stools of perennial grasses from which the protecting mantle of dry material is broken away so as to give ready access to young green shoots are often grazed to extinction, with the formation of a bare patch of ground.

(vii) *Sown Pastures.*—Yields of introduced pasture grasses have in general been good, exceeding by several fold that of the native pasture. In spacing trials, some species have shown no tendency to fill in, whilst others have tended to form swards. As swards generally have lower production, the tendency to fill in could be detrimental.

(*b*) *Kimberley Research Station.*—(i) *Crops.*—*Sugar cane.*—Crops continue to show improvement as knowledge of management increases. Experiments on time of planting indicate that planting in the cooler months of May, June, and July is desirable rather than in the hotter, later months, for early

planted cane-tillers well before jointing commences. They are several instances where over 100 tons of cane per acre have been reaped over a three-year period. Sugar content, especially of the canes harvested later, remains good, with an average commercial cane-sugar content of around 14 per cent.

Rice.—Cultivation has been expanded so that about 20 acres are now under rice, with some bulk plots grown on a semi-commercial scale. Harvests are very encouraging. Mean yields of up to 1½ tons paddy per acre have been recorded in replicated variety trials. Work so far has been concentrated on varieties suitable for growing in the summer period, but parallel investigations are now in progress to determine the possibility of growing rice in the cooler, dry season.

Safflower.—Yields of up to 1,500 lb./acre were obtained from bulk plantings, but the crops were not altogether satisfactory.

Other Crops.—Wheat did not do as well on continuously cropped land as on a fallowed area in the previous season. Oats showed promise on the levee, and both oats and barley are currently being grown on the clay soil. Sunflowers gave a low yield, mainly resulting from a low percentage of seed-setting. Attempts to establish ramie from seed were not successful.

(ii) *Fertilizers.*—Sugar cane responds to dressings of 4 cwt. each of ammonium sulphate and superphosphate, and current experiments are designed to measure responses to still higher levels. Rice shows only a small response to either ammonium sulphate or to superphosphate applied singly on virgin land, but responds markedly when they are combined. On land which had carried rice in the previous year, phosphate alone showed a good response, which is in accordance with soil tests indicating that the previous crop had improved the nitrogen status of the soil.

(iii) *Irrigation.*—Rice required from 3¼ acre feet of applied water for the early maturing varieties to twice this amount for later varieties.

(iv) *Diseases.*—All major crops remained substantially free from diseases. Tobacco was affected by a virus diseases not hitherto recorded in Australia—tobacco leaf curl. This virus has now spread to tomatoes.

(v) *Pests.*—Rice stem borers which did much damage to the 1953-54 rice crop re-appeared in the current season, but frequent dusting with BHC has given substantial but by no means complete control. This pest still remains a major hazard to rice-growing.

(vi) *Pastures.*—The beneficial effect of *Clitoria ternatea* on associated grasses has again been apparent. Where *Clitoria* has been overgrazed, it is not standing up to competition with the less palatable grasses such as *Andropogon gayanus* and *Cenchrus ciliaris*. Where over-grazing is avoided, *Clitoria ternatea* continues well with these grasses. A pure stand of *Clitoria ternatea* has persisted and yields hay at the rate of 1 ton of dry matter per acre per year, and also provides a few months of intermittent grazing.

4. Climatology.

(Land Research and Regional Survey Section.)

During the year the climatology unit has continued to provide general climatic information to other units of the Section, and to pursue a specialist research programme in soil-plant-atmosphere water relations.

The reports on the climates of the Buna-Kokoda and Leichhardt-Gilbert areas have been enlarged by the inclusion of further information and are now complete, awaiting inclusion in the general report on the areas. A further report has been compiled on the climate of the King Edward-Drysdale area to accompany the general report on the recently completed survey of this region.

At Kimberley Research Station an experiment with crops of cotton, sunflowers, and grain sorghum has just been completed. This experiment had the principal objective of assessing the influence of atmospheric and soil moisture conditions on the growth and development of the crops under study and on their rates of water use. Two soil moisture treatments were imposed, one of which comprised natural rainfall alone, and the other frequent irrigations so that little soil moisture stress existed at any time. Only two periods of dry weather of any severity occurred during the season, but the growth of the plants in the irrigated part of the experiment was considerably faster than in the part receiving natural rainfall alone. Other measurements taken included those of leaf turgor and evapotranspiration.

An exploratory experiment at Alice Springs was commenced during the year to determine the balance between water intake and water loss in an area of natural mulga woodland on the Burt Plain, just north of Alice Springs.

A comprehensive experiment on an area of natural vegetation at Kimberley Research Station has been commenced with the objective of determining the water balance of the area, and the rates of water use, growth and production of the plant community and its individual species. The experiment may extend for more than one season and it is hoped that a complete water balance will be achieved from the opening rains of the season through until the onset of the dry season drought.

Observations on water losses from fallow soils during the dry season were continued at both Katherine and Kimberley Research Stations in collaboration with officers at these centres. Although the data are still being studied, preliminary indications are that so much more water is lost from soils which remained fallow during the previous wet season than from soils which were dried to approximately the permanent wilting percentage by crops, that little purpose is served by fallowing as a water conservation measure from season to season.

5. Arid Zone Research.

(Land Research and Regional Survey Section.)

Investigation of the plant ecology of Central Australia has continued over a wide area. Some 15,000 miles of traverses were made to cover two-thirds of the pastoral areas. This initial work is of necessity on a broad scale. It will permit the definition and description of the major plant communities within the next few months. Vegetation boundaries were marked off on traverses. This information will facilitate the future detailed mapping of vegetation. The relationships of these communities to soil type, topography, and drainage conditions have been partly defined.

Extensive collections of plants were made and during visits to various herbaria the identifications of nearly 200 plants were completed. This is in addition to 300 identifications made locally.

Soil moisture studies were commenced in co-operation with a Climatology unit in a mulga woodland community by means of the gypsum block technique. The progress of penetration of rainfall and subsequent drying of the soil, which occurs over relatively short, defined periods of the year following rains, is recorded in conjunction with recordings of rainfall. Determinations of soil field capacity and wilting percentage indicated a small range of available moisture, but it is apparent from results to date that certain native grasses are surviving when soil water tension exceeds the generally accepted limit of available moisture.

It is hoped that the results will provide information on season production of vegetation in relation to rainfall and soil moisture.

XII. FISHERIES.

1. General.

The acquatic resources of Australia, including whales, the more important commercial fish, crustacea, and shellfish, require study to ensure their economic use and, where necessary, their management to prevent depletion of stocks. Fundamental to this study is an examination of the environment to ascertain the variations in oceanographic and estuarine conditions which affect organic productivity and are to a large extent responsible for fluctuations in fish occurrences. Through its Division of Fisheries the Organization provides facilities for these studies.

Division of Fisheries.—The first Chief of the Division, Dr. H. Thompson, retired in December, 1954, after almost eighteen years of valuable service in that position, and he has not yet been replaced. Consequently no new major projects or reorganization were undertaken during the year.

An important feature of the work of the Division as a whole was the closer integration of studies on important animal populations and on their environments. In applied research special attention was given to the whale, crayfish, and pearlshell fisheries, which in 1953-54 yielded Australia the record export income from marine products of £4,600,000.

The vessels and crews maintained a high standard of performance. A wide range of work is now regularly carried out in ocean waters hundreds of miles offshore. There is still, however, a very pressing need for a vessel large enough to use the trawl, to take more scientists to sea at a time, and to provide facilities for the processing of material at sea.

Three officers were overseas: one was invited to a meeting in Rome to advise upon a U.N.E.S.C.O. Advisory Committee on Marine Sciences, to which he was subsequently appointed; one attended the United Nations International Technical Conference on the Conservation of the Living Resources of the Sea at Rome as scientific adviser to the Australian delegation; and one employed part of his leave in an investigation of the microbiology of New Zealand hot springs. Officers also attended the conference of the Pan Indian Ocean Science Association at Perth.

Visitors from overseas included fisheries workers from India and the South Pacific Commission.

The foundations of a programme of more intensive research on ship fouling were laid with the assistance of the Royal Australian Navy.

The Division is again indebted in various ways to the Universities, especially Sydney, Queensland, and Western Australia; to all State Departments of Fisheries, the Commonwealth Fisheries Office, and the Tasmanian Salmon and Freshwater Commission; to the Australian Museum, Sydney; and to other Divisions of C.S.I.R.O., especially Electrotechnology, Food Preservation and Transport, Entomology, and Mathematical Statistics. The valuable assistance of the Australian Whaling Commission and the four private whaling companies in arranging co-operation and accommodation, and of Messrs. Huddart Parker Co. in collecting seawater samples, likewise merit special note.

2. Operations of Research Vessels.

(Division of Fisheries.)

(*a*) *F.V.R. Derwent Hunter.*—Six cruises were made from the home port of Hobart. Cruises 11, 12, 14, and 15 were quarterly fishing cruises, each of about two weeks, in east Tasmanian waters. Cruise 13, from 13th October to 23rd December, was an oceanographical survey of Bass Strait and the south-west Tasman Sea (between S. lat. 34° and 43° and E. long 148°and 156°). On Cruise 16, from 6th April to 31st May, similar oceanographic work was done in Bass Strait and in the Tasman Sea (between S. lat. 37° and 43° and E. long. 148° and 152°).

(*b*) *F.R.V. Gahleru.*—Twelve cruises, each of from one to six weeks, were made from the home port of Thursday Island. One was to Groote Eylandt and the Crocodile Group, Northern Territory, and the others were in Torres Strait, all cruises being concerned with pearl shell investigations.

3. Fisheries Biology.

(Division of Fisheries.)

(*a*) *Whales.*—During the whaling season (June to October) of 1954, all five Australian whaling stations were visited in order to collect further data upon reproduction, growth, and general conditions of the two stocks (western and eastern Australia) of humpback whales.

At the close of the season an annual report was prepared for submission to the International Whaling Commission. It was shown that on the Western Australian coast the adverse trends apparent in the 1953 season continued during 1954. The percentage of females in the catch increased, the mean lengths of both sexes continued to fall, the length frequency distribution moved towards the lower length ranges, and the percentages of immature whales continued to rise. For the eastern coast the corresponding analyses did not indicate any significant decline in the stock over the past three years. In Antarctic area IV. (70° E.-130° E.), where Western Australian humpbacks go in summer, there has been a decline closely similar to that found in Western Australian catches over the same period.

The annual quota of humpback whales from the Western Australian coast has accordingly been reduced by the Commonwealth Fisheries Office from 1,320 to 1,120, to preserve the stock.

An extensive range of biometrical material from humpback whales of western and eastern coasts of Australia is being analysed. Significant differences between western and eastern groups have been found.

Investigations continued on puberty, sexual maturity, physical maturity, and relative growth rate of the female humpback, and further work is being done upon reproduction in the female. More small embryos were obtained.

Sixty whales were marked in eastern Australia and 25 in Western Australia. One mark was recovered shortly after firing.

(*b*) *Sea Fish.*—(i) *Barracouta* (Thyrsites atun).—The commercial catch of 4,300,000 lb. (beheaded and cleaned) in 1953-54 was the lowest since 1941-42. The adverse conditions of the previous three years recurred in Bass Strait, and on the east coast of Tasmania, where fishing had been good in most recent years, the situation was even worse.

As in former years, the scarcity of barracouta in Bass Strait was much more marked in some areas and months than in others; for instance, it was most evident in autumn and scarcely noticeable in spring. Since all Bass Strait barracouta appear to belong to the same population the disturbing condition is probably unusual behaviour, rather than small size, of this population. Plankton surveys in the autumn of 1954 and 1955 revealed good quantities of the euphausian *Nyctiphanes australis*, the main food of barracouta at that season, in Bass Strait, but concentrated in offshore areas. It seems likely that most of the fish were in these areas and therefore unavailable to the coastal fishermen.

(ii) *Australian Salmon* (Arripis trutta) *and Ruff* (A. geogianus).—Australian salmon was the most important species in the Australian fish catch in 1953-54, with a record yield of 11,400,000 lb. *A. geogianus.*

Data collected on size distribution and migratory and reproductive behaviour strengthened the previously formulated hpothesis that the salmon of Western Australia, South Australia, western Victoria, and western Tasmania, are of the one stock, this stock having a marked migratory behaviour. The Western Australian fishery is concentrated upon the larger size-groups, the South Australian fishery on the smaller.

Further study has supported the view that spawning of the western subspecies takes place only in Western Australia. South Australian males showed spermatozoan development during the autumn of 1955, but sampled females showed no developing ovaries. Recent results from tagging experiments suggest a large-scale migration from South Australia to Western Australia, to spawn there. Of the 4,000 tagged salmon released up to date in South Australia 320 recoveries have been obtained from South Australian waters and eighteen from Western Australian waters.

Further work on the ruff in South Australia and Western Australia has confirmed the view that the general behaviour pattern of this species is similar to that of the western subspecies of salmon. The smaller size-groups occur in South Australia, where only one female showing ovarian development has been recorded. A further eight movements of tagged fish from South Australia to Western Australia, making seventeen in all, were noted.

(iii) *Trawl Fish.*—An examination of the present condition of the New South Wales trawl fishery indicates that the overfished New South Wales stock of tiger flathead (*Neoplatycephalus macrodon*) remains at a low level and would probably reach even lower levels if fishing intensity remained as high as in 1953-54. There is still every reason to expect that if fishing effort were reduced to approximately 3,500 trawler tons an improvement in catch per unit effort and total catch would result.

With the recent cessation of operations of one of the two steam trawler companies and the shipwreck of two steam trawlers, some reduction in fishing effort, from 5,184 to about 4,564 trawler tons (estimate), did occur in 1954-55. The latter figure is still much in excess of the suggested optimum fishing effort of 3,500 trawler tons.

A full market sampling programme has been continued throughout the year, with particular attention given to morwong (*Nemadactylus macropterus*) and nannygai (*Trachichthodes affinis*).

An officer was stationed at Lakes Entrance, Victoria, in December, 1954, to make a twelve months' study of the Danish seine fishery of that region. It is necessary, for the management of this fishery, to know whether the tiger flathead of this region is of the same population as that in New South Wales.

(iv) *Demersal Fish of the Continental Slope.*—Field work has been continued at intervals throughout the past year off the east coast of Tasmania. Fishing experiments have aimed at testing hypotheses concerning seasonal changes in bathymetric distribution, feeding, spawning, and general availability of the important teleost species: *Hyperoglyphe porosa* (deep sea trevally), *Genypterus blacodes* (ling), and *Mora* sp. (deep sea cod).

The new method of droplining, which was introduced in June, 1954, has proved a most efficient means of obtaining trevally in quantities exceeding any recorded previously. However, this technique is good only for trevally, so that longlining has been continued in order to obtain data on the ling and cod.

Results obtained over the past year employing both techniques have served to confirm, at least in part, the current hypotheses. The main concentration of trevally, which during winter is close to the 300-fathom contour, gradually moves up the slope until it reaches its shallowest limit in summer at about 230 fathoms. No such change has been observed for ling and cod.

The spawning seasons for both trevally (summer) and cod (winter) have been established. Evidence of spawning or indication of its season is lacking, as yet, for the ling.

(v) *Tuna.*—The 1954-55 season for southern bluefin tuna (*Thunnus thynnus maccoyi*) in New South Wales opened very promisingly. However, because of falling prices overseas and lack of freezer space, catch quotas were enforced and only about 550 tons were taken.

From June to early September, 1954, a reconnaissance of the entire east coast of Queensland was made by two tuna vessels by arrangement with the Commonwealth Fisheries Office. Observers from the Division were aboard. Tuna and bait fish were scarce within Great Barrier Reef waters, but outside the Reef, especially in the Swains and Frederick Reef areas, promising results were gained by trolling. The principal tuna species caught were dog-tooth tuna (*Gymnosarda nuda*) and yellow-fin tuna (*Neothunnus macropterus*).

In May, 1955, a tuna longline was used once with moderate success from the F.R.V. *Derwent Hunter* off the east coast of Tasmania. Poor weather conditions and several weaknesses in the construction of the line prevented extensive testing. Large fish to 200 lb., seldom seen in the coastal troll fishery, were taken.

(vi) *School Shark* (Galeorhinus australis) *and Gummy Shark* (Emissola antarctica).—The investigation of school shark has practically ceased, the main interest being centred in the tag returns still being received from widely separated fishing localities. All have confirmed the previously expressed theories on migration and rate of growth. In all, 6,273 school sharks have been tagged and 300 recovered.

An attempt is being made to analyse the catch statistics of the school shark fishery. Further advice has been tendered to State and Commonwealth Fisheries Departments regarding conservation measures.

Further tagging of gummy shark brought the total number tagged to 562, of which ten have been recaptured.

(c) *Estuarine Fish.*—(i) *Lake Macquarie Investigations.*—The study of the mixed estuarine fishery of Lake Macquarie, New South Wales, was continued, and a study of the bottom fauna begun.

Twelve months' full-scale tagging was completed in May, 1955: 16,727 fish of all species were tagged.

The proportion of tags returned by anglers suggests that they take significantly great numbers of fish from the lake. Certain species, e.g., flat-tailed mullet, move around the lake continually. Other fish, such as leatherjackets, remain in one vicinity for prolonged periods until their spawning migration takes place. Other species, e.g., bream and squire, show an intermediate type of behaviour. Yellow-finned leatherjackets and sea mullet make large-scale movements from the lake.

Commercial net fish are abundant. Ground fish such as flathead and whiting are relatively scarce, probably because of shortages of suitable food. There is some indication that black bream are overfished.

(ii) *Western Australian Investigations.*—The data on the biology and catch statistics of yellow-eye mullet (*Aldrichetta forsteri*) are at an advanced stage of analysis. The population level is extremely variable, as a result of variable survival of eggs and fry. There is biometric and physiological evidence that the yellow-eye mullet of Victoria and Tasmania are racially distinct from those of Western Australia.

A study of the times of spawning, size at first breeeding, and food preferences of the commercial estuarine fishes of Western Australia has commenced.

(iii) *Sea Mullet* (Mugil cephalus).—A study of the movements of mullet within an estuarine system shows that the mullet school persists as an entity, although some emigration from (and presumably immigration to) the school takes place. Considerable range in behaviour is displayed by individual schools. Evidence suggests that most adult fish participate in the spawning migration only every second or third year.

(iv) *Barramundi* (Lates calcarifer).—This study is nearing completion. The only fishery of economic importance occurs in central and northern Queensland waters and in the Gulf of Carpentaria. The opportunity for migration to suitable breeding areas, spawning, and establishment of fry and fingerlings depends on past and present climatic conditions and on river types.

A further 900 fish were tagged for the year. The return of ten tags confirmed the previously held hypothesis regarding very rapid early growth rate and catadromous behaviour. Morphometric studies revealed differences between stocks inhabiting the east coast of Queensland and the Gulf of Carpentaria and between fresh (i.e., land-locked) and salt-water inhabitants.

Catch statistics revealed a noticeable decline from a peak figure in 1947, related to illegal freshwater fishing and the taking of undersized specimens.

(*d*) *Freshwater Fish.*—(i) *Trout* (Salmo *spp.*) *Investigations in Tasmania.*—A report has been written covering the fishery of the north-west region in all its aspects based on analyses of anglers' returns supplemented by field operations and scale readings. It has been possible to assess mortality rates, from which it has been shown that there is little justification for the artificial hatching and rearing of fish for liberation in these streams. Preparatory work for a similar report (scale-readings and analyses of anglers' returns) has been completed for the north-east region.

During the 1954 spawning runs, 1,352 brown trout and 751 rainbow trout were examined at Lake Leake. Comparable figures for the Great Lake were 7,614 brown and 860 rainbow trout. During the spawning run in the Plenty River, 600 fish passed through the fish trap.

The electrical fishing apparatus has been put to good use during the past season. A survey of the North Esk River (reported by anglers to be devoid of fish), during which the river and its tributaries were sampled at 25 places totalling 1½ miles of river bed, yielded 890 trout. A rough computation shows that there should be not less than 80,000 trout, of which 17,000 are of takable size, above the lowest point fished.

(ii) *Fish Culture Investigations in Tasmania.*—In June, 1954, the eight-acre dam at Dairy Plains, near Deloraine, was restocked with some 4,000 brown trout fingerlings. Special provision was made beforehand for the draining of the dam, and it is proposed to recover the fish in June, 1955, so that growth and mortality may be assessed.

Some knowledge has now been obtained of the biological and chemical characterists of four typical farm dams, which it is intended to stock with fish. Two dams have communities of higher plants and are richer in phytoplankton and bottom fauna than the other two. Zooplankton is well established in two of the dams. One of the dams without higher plants has bottom-living algae in large numbers. Several methods are being tested to see whether the mud of the dam can be forced to yield up some of its nutrients to the overlying water.

Biological information about tench (*Tinca vulgaris*) and perch (*Perca fluviatilis*), which will be used in the dams, is being sought. Work on tench is nearing completion. Preliminary holding of tench in dams has shown that they grow very well, even under poor conditions.

(*e*) *Crustacea and Shellfish.*—(i) *Western Crayfish* (Panulirus longpipes).—The total catch rose to 10,300,000 lb. in 1954.

The data obtained from the continuous crayfishing test at Pelsart Group, Houtman Abrolhos, in 1953, have been analysed. Changes in catching rates resembled those in the similar test of 1948. The average number of crayfish per haul was 90 in 1948 and 37 in 1953. Seventeen marked crayfish were recaptured within two miles of the point of release from one to thirteen months later, and three at a distance of 30 to 35 miles.

The collection of length-weight data was completed, and analysis is proceeding in order to convert crayfish landings by weight to numbers in the various size classes. Statistical study of the Abrolhos crayfishery has been continued.

The study of the reproductive cycle of the crayfish was continued. Spawning times appear to vary from group to group of islands in the Abrolhos. A self-contained diving unit was used with great advantage in various branches of the crayfish investigation.

(ii) *Southern Crayfish* (Jasus lalandii).—Plans were made for an investigation of the fishery for this species in Tasmania where the rate of catch, although not the catch itself, is falling in most areas.

(iii) *Prawns.*—Further surveys were carried out in co-operation with the Western Australian Department of Fisheries from Exmouth Gulf to the Dampier Archipelago. *Penaeus esculentus* (the tiger prawn) was taken in fair quantities, with increase of numbers and progressive ripening of gonads during the winter and spring period.

(iv) *Pearl Oysters* (Pinctada *spp.*).—*Spattings.*—It has now been found that the almost universal absence of the 0+ age group in samples of *P. maxima* is due to the inability of divers to see them. Beds on which no 0+ group oysters have been seen in the past three years carry plenty of the 1+ and 2+ groups.

Age at First Maturity.—It was confirmed that *P. fucata* and *P. albina* usually mature in their first year and that oysters setting only a few months before the major spawning season may reach maturity in that short time. In *P. maxima* half the first year population, 90 per cent. of second year population, and all third year oysters show signs of sexual development.

Change of Sex.—Data from tagged specimens of *P. maxima, P. fucata,* and *P. albina* showed that there may be a female-male change in addition to the initial protandric sex-change.

Gametogenesis.—It is now possible to determine accurately the state of maturity of pear oyster gonads by histological examination, and many intergrading stages of development and resorption can be recognized. Spawning is often incomplete and resorption of unspawned material occurs, at least in the testis.

Tagging.—Further tagging has been carried out on the Mainland Ground to confirm growth rates estimated by other means.

Length-Weight Relationships.—This work has been extended to samples of *P. maxima* from the Northern Territory and Western Australian areas. It now appears that there is a definite geographical variation in the relationships: western shell is more convex and heavier than eastern, for a given diameter.

Induced Spawning (for *shell culture*).—Ripe specimens of *P. maxima* can be induced to spawn in November, December, and January by raising the temperature of the water 4–5° C. and adding sperm suspension. Experiments on artificial maturation of ova, using ammoniated sea-water solutions, gave promising results.

Pearl Culture.—Nuclei have been inserted in specimens of three species, the majority of which survived the operation and retained the nuclei. In one case (*P. margaritifera*) the graft seemed to have taken.

(v) *Scallops* (Notovola meridionalis).—The Tasmanian scallop beds were examined as usual during the 1954 season. The brood of 1948 entered the fishery with an expected low meat weight of 26 lb. per 1,000. The quality and meat yield can be expected to increase slightly next year, maintain the approximate quality for another year or so, and then fall. The main Channel beds carried large quantities of two-year-old scallops, showing that good spatfall occurred in 1952.

(vi) *Oysters.—Japanese Oysters* (Ostrea gigas).—Growth of maturing stock in Port Sorell has been normal. A limited spatfall occurred in March, 1954, but only half survived. Mass spawning occurred in March, 1955, and a settlement of young oysters may occur.

Sydney Rock Oyster (Crassostrea commercialis).—In a programme to sample the food available the following results have been obtained:—the number of food organisms diminishes as height above mud increases; there is close similarity in counts over one tidal period or several tidal periods; a high percentage of the plankton is under 5μ; zooplankton maxima have been apparent but blooms in phytoplankton have not been noticed.

Work on winter mortality has been revived as a co-operative study between an officer of the Division and a world authority on oyster diseases. Little mortality occurred in 1954.

4. Ichthyology.

(Division of Fisheries.)

(*a*) *Reference Catalogue of Australasian Fish.*—The catalogue has been kept up to date and several hundred illustrations have been added.

(*b*) *Handbook of Ceylon Fishes.*—The illustrated handbook of fishes of Ceylon, which is being published by the authority of the Department of External Affairs as a project under the Colombo Plan, will soon be available for distribution in Asian countries.

(*c*) *Check-list of New Guinea Fishes.*—The identification of fish collected by M.V. *Fairwind* during 1948 and 1949 has been completed. The check-list of New Guinea fishes has been revised to incorporate the records of the *Fairwind* collections. These increase the number of species known from the Australian territory from 821 to 1,003 and that for the whole region from 1,321 to 1,423.

(*d*) *Fish Eggs and Larvae.*—Most of the postlarval fishes obtained in New Guinea by M.V. *Fairwind* have been identified. Further experimental studies have been carried out on the hatching of eggs of estuarine species and on the determination of spawning seasons and breeding habits.

5. Hydrology.

(Division of Fisheries.)

(*a*) *Oceanic Investigations.*—(i) *Tasman Sea.*—The data on surface salinity and temperature collected by T.S.M.V. *Wanganella* since 1953 have now shown that the east Australian current, flowing southward each spring and summer, is composed of two water masses. One originates in the Coral Sea and reaches its maximum flow in December and the other is of sub-equatorial origin and flows between New Zealand and New Caledonia, reaching its maximum velocity about February or April. However, the major characteristics of the Tasman Sea surface waters are developed by mixing between the surface water mass moving southwards from the Coral Sea and the deep water mass moving northwards from the sub-Antarctic.

By local modification of the secondary water mass thus formed, the various water masses occurring along the east Australian and New Zealand coasts are formed. A major variation in the flow of either the Coral Sea or the sub-Antarctic water mass can alter the composition of all derived water masses accordingly.

The fertility characteristics of these water masses have been ascertained and the influence of water movements on the development of these characteristics is more clearly understood.

(ii) *Bass Strait.*—The cruises of the F.R.V. *Derwent Hunter* in this region have enabled a knowledge of the principal water masses and their fertility characteristics to be built up. The location and seasonal movement of a water mass of very low fertility has been studied.

A low-temperature water mass, which presumably encircles the Tasmanian mainland at certain times of the year and competes in summer with the warm water from New South Wales for dominance of the east Tasmanian coast has also been identified. In the eastern approaches to Bass Strait there is a warm fertile water mass; elevation of rich bottom water by canalization along the Snowy River submarine canyon may contribute to its formation.

The trans-Bass Strait sampling from the M.V. *Taroona* has been continued.

(*b*) *Coastal Investigations.*—(i) *East Australia.*—The cycle of hydrological changes in east Australian waters, which commenced in 1942 and led to a big change in total phosphorus, salinity, and temperature of these waters, came to a climax in 1951-52. The most promising approach to the study of this cycle has been developed with the aid of recent *Wanganella* and *Derwent Hunter* results in the Tasman Sea.

The summer oceanographical conditions off Port Hacking, New South Wales, which seem to control the annual fertility of these waters, are dominated by the composition of the water mass flowing southward in November-December of each year. This early-summer water mass is composed of a mixture of Coral Sea and sub-Antarctic waters, mixed by vertical exchange during their southward and northward movements respectively. If the relative flow strength of either of these water masses is varied, so is the composition of the water mass occurring in any latitude. Analyses of Port Hacking and Maria Island (Tasmania) waters in the month of December during the period 1942-54 show that years of high total phosphorus are associated with greater sub-Antarctic influence and years of low total phosphorus with greater Coral Sea influence.

(ii) *South-western Australia.*—Fortnightly sampling was continued during the year at the Rottnest Island 50-metre station. The pronounced fall in chlorinity observed during the early winter of 1952 and 1953 was attributed to the southerly movement of warm water of low density, but there was no comparable decrease in 1954.

(*c*) *Estuarine Investigations.*—The studies on the hydrology of Lake Macquarie, New South Wales, were continued. It was found that the sudden changes in water level within the lake are not only related to outside sea levels, but also to winds and barometric pressure over the lake itself. There is an inverse relationship between high nutrient concentrations in Dora Creek (a tributary) and the appearance of high nutrient peaks in the waters at the bottom of the lake, which has not yet been explained.

The work on general hydrology and circulation of the Swan River (Western Australia) was written up. Some work remains to be done on phosphate and nitrogen cycles and the effect of water level on circulation characteristics in the spring period.

The studies at Pittwater and Port Sorell, Tasmania, have been continued.

(*d*) *Productivity Studies.*—The work on the role of turbulence in elevating the organic detrition of the mud surface to critical levels above the mud surface for oyster growth has been continued.

A critical check on the methodology of collecting samples for chlorophyll estimates has shown that filtration under pressure, whilst superior to tow netting, is still very inefficient. A high-speed continuous centrifuge of the "Forset" type has enabled almost complete separation of the microplankton to be effected.

(*e*) *Instrumentation.*—The Chainomatic Pycnometer was developed during the year and an American firm is now manufacturing it for general use. An oscillatory bridge type of meter with automatic compensation of conductivity for temperature has been designed to give direct readings of chlorinity and temperature, the former property on a limited range only. A commercial model of this instrument with greater range is being manufactured locally. The first sea trials of the salinity-temperature-depth recorder were carried out successfully.

6. Planktology.

(Division of Fisheries.)

The major part of this study is being carried out in conjunction with hydrological and fisheries investigations in Bass Strait and the Tasman Sea. Copepods, euphausians, medusae, and tunicates received most attention during the year.

Special attention was paid to the euphausian *Nyctiphanes australis,* already mentioned in connexion with barracouta. The two principal euphausians of the Tasman Sea, *Euphausia recurva* and *E. lucens,* are generally found respectively north and south of 40° S. latitude, except near the Tasmanian east coast where *E. recurva* sometimes occurs further south. No part of the Tasman has yet been found to be as productive of euphausians as the neritic waters of Victoria and Tasmania.

A plankton survey of the Exmouth Gulf area (Western Australia) was made in the winter of 1954. Collecting ceased in Lake Macquarie, New South Wales, and the work was written up.

7. Microbiology and Botany.

(Division of Fisheries.)

Work on microbiological processes in the estuarine environment, with special reference to the sulphur cycle in bottom muds, was rounded off and submitted for publication.

The importance of the sulphur work warranted a brief study of sulphur formation in Lake Eyre, South Australia. The sulphur was found to be of microbiological origin. As a further extension (in part) of this work, the microbiology of hot springs was studied by an officer on leave in New Zealand.

Phosphate release with hydrogen sulphide from ferric, ferrous, and calcium orthophosphate was studied, as the process is believed to be important in the phosphate cycle in estuarine mud and water.

Data were gathered on the electrode potentials and pH of various natural environments.

Estimations were made of the density of the *Zostera* plant and its epiphytes in New South Wales estuaries. Certain fish feed on the epiphytes and others on the *Zostera* itself. *Enteromorpha,* the main alga of the estuarine and mud flats, was also studied.

The bottom muds of Lake Macquarie have an unexpectedly low redox potential, and diatoms and flagellates are scarce, although the muds are well within the photic zone. The aerobic bacterial counts of these muds are also rather low.

8. Fouling.

(Division of Fisheries.)

The accumulated results of several years' work on the principal fouling organisms of the New South Wales and Queensland coasts were written up, work was continued on the important fouling group of serpulid worms, and a new programme of ship fouling investigations was drawn up at the request of the Royal Australian Navy. Results of inquiries into the treatment of fouling in sea-water cooling systems, made in the United States in 1954, were reported to organizations concerned.

XIII. FOOD.

1. General.

The preservation of food is an increasingly important link between primary industry and the consumer market. There is a growing awareness of the part which science and technology can play in reducing wastage, improving quality, and generally raising the efficiency of Australia's food processing industries. The complex constitution of foodstuffs of all kinds, especially meat, dairy products, and fruits, calls for fundamental studies based on physics, chemistry, botany, and bacteriology to ensure the elimination of processing and storage conditions which tend to their deterioration. As a major food producing country situated far from the main food importing nations, and with its own population centres separated by long distances, Australia has a special interest in the preservation of foodstuffs during transport.

The Organization's work on food is undertaken chiefly within the Division of Food Preservation and Transport with its main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane, Queensland (meat); West Gosford, New South Wales (citrus fruits); Eden, New South Wales (fish); Hobart, Tasmania (fish, apples, and berry fruits); and at the Botany and Biochemistry Departments, University of Sydney (plant physiology and physical chemistry). The work of the Division is described in Sections 2-11 of this Chapter. Work on the manufacture of dairy products is carried out by the Dairy Research Section at Highett, Victoria (*see* Section 13 of this Chapter). Co-operative investigations on wines are carried out in the Waite Agricultural Research Institute (*see* Section 12 of this Chapter).

Work on dried vine fruits is in progress at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria (*see* Section 14 of this Chapter).

Division of Food Preservation and Transport.—In view of the increasing urgency of the technical problems in the preservation and transport of meat for export, a substantial part of the Division's resources is now devoted to meat investigations which are mainly located in Brisbane. Dr. R. A. Lawrie, of the Low Temperature Research Station, Cambridge, returned to Australia in May, 1955, to resume a series of investigations in co-operation with the Division's officers. Additional equipment has been installed in the meat investigations laboratory, including a large blast freezing tunnel capable of freezing a hindquarter of beef in the fast time of 12-14 hours.

Drying from the frozen state is the preferred method of preservation of microbial cultures, and investigations have been proceeding for some time on the conditions governing the death-rate of microorganisms subjected to this form of preservation. It has been found that the death-rate can be very greatly reduced during storage by the addition to the cultures of substances, such as sulphur dioxide, which will block the reactions between reducing sugars and the amino side chains in the microbial proteins. This discovery will have a wide industrial application, and a patent application covering the process has been lodged.

While the Division relies on such bodies as the several State Departments of Agriculture and the Commonwealth Department of Commerce and Agriculture to disseminate the results of a major part of its research work, the Division's officers have carried out a considerable amount of extension work chiefly through the Division's publication "Food Preservation Quarterly" and through many professional and technical associations, such as the Institute of Food Technologists, the Australian Canning Convention, and the Commonwealth Cold Storage Association. In March, 1955, a conference of technical people from the meat export industry was convened in Brisbane in order to acquaint the industry with the results obtained in the Division's meat investigations laboratory during the last few years and also to seek the help of the industry in formulating a research programme for the next four or five years. In conjunction with the Dairy Research Section, the Division organized an attractive stand at the Better Foods Exhibition held in Melbourne in January.

Considerable assistance has been given to the authorities responsible for the supply of food to the Defence Forces, particularly in the design and testing of a number of components of the new one-man 24-hour ration. Extensive tests have also been carried out on a wide range of canned foods stored at Mawson, Antarctic Dependency.

2. Physics.

(Division of Food Preservation and Transport.)

(*a*) *Evaporation of Moisture from Foods in Cold Storage.*—A comprehensive study of this subject is in progress, and a good deal of work on the following aspects of it has been carried out during the year under review.

(i) *Evaporation Properties of Particular Foodstuffs.*—The techniques of measurement have been improved and data obtained with apples, oranges, apricots, plums, and peaches.

(ii) *Effects of Packing Fruit in Cases.*—Work reported last year has been continued. Further data have been obtained with apples and oranges in several types of package and theoretical analyses of the problems have been carried further.

(iii) *Properties of Particular Stores.*—Several frozen stores have been studied using the weight losses from standard blocks of ice as a measure of the drying power of the storage atmosphere. Quite large positional variations have been found in natural circulation stores.

(iv) *Evaporation from Meat in Storage.*—Experiments have been begun to obtain evidence on the variation in weight loss through stacks of frozen carcass meat and on the evaporation properties of frozen carcasses and their variation with the previous history of the meat and the storage conditions.

(v) *Theoretical Analyses.*—Such analyses of the whole system—store, cargo, and cooler—have been carried a little further.

(*b*) *Freezing of Meat.*—Some difficult engineering design problems arise from the desire of many meatworks managers to reduce the time taken to freeze meat. Consequently the possibilities of obtaining a fairly precise prediction of the performance of a projected freezer have been studied. Much work remains before this can be done with high accuracy but some progress has been made.

There is a good deal of interest in the industry in the practice of loading meat into air-blast, rapid freezers without prior chilling, because this can reduce the cost of meatworks operations. For the design of such freezers it is necessary to be able to estimate the effect of the initial temperature of the meat on the freezing time. A little work has been done on this overseas but the formulae derived from it are inconsistent with some experimental data obtained in the Brisbane Laboratory. Consequently, some numerical integrations of the differential equations describing the process have been carried out. These showed that the heat transfer coefficient from the surface has a marked influence on the effect of the initial temperature and that the apparent inconsistency between the Australian and overseas data can be accounted for by the difference in the rate of heat transfer from the surface in the two series of experiments.

(*c*) *Conduction Errors in Thermocouples.*—The experiments referred to in the last Annual Report have been continued but are not yet complete.

(*d*) *Performance of Cold Stores for Fruit.*—The analysis of the data collected over several years and the preparation of a comprehensive report on the work have now been completed.

(*e*) *Freezing of Bread.*—Some measurements have been made with a few types of bread and calculations carried out in order to provide data needed for the design of commercial freezers for bread.

(*f*) *Water Relations.*—As part of the programme on the study of proteins the vapour pressure isotherms at 30° C. of several proteins have been obtained by direct measurement of vapour pressure. Work is in progress to improve the equipment so that the water content of a sample can be found more directly.

Further data have been collected on the water content of foodstuffs in equilibrium with atmospheres of known relative humidity. A report of observations on dried vine fruits is in preparation.

(*g*) *Colour Measurement.*—Spectral reflectance curves of some foodstuffs have been obtained to serve as a basis for the development of simple routine methods of colour grading. Attempts are being made to overcome difficulties due to drift and lack of sensitivity in the electrical circuits of the photoelectric tricolorimeter so that it will be more suitable for routine work.

3. Food Chemistry.

(Division of Food Preservation and Transport.)

(*a*) *Volatile Products of Apples.*—The organic volatile substances produced by fresh apples are concerned in the aroma and possibly also in the control of ripening. There is evidence of some relation between volatile substances and superficial scald, a functional disorder.

No volatiles other than those previously identified have been detected in the course of varied experiments. The effects of these volatiles in causing scald were studied systematically and a positive result was obtained with esters of higher alcohols.

(*b*) *Natural Coating of Apples.*—The studies on the natural lipid coating of apples are related to the physiological behaviour of stored fruit, as the natural coating is the main barrier to gaseous diffusion and thence influences the composition of the internal atmosphere. The chemical constitution of the oil and cutin fractions is being investigated.

A paper on the identification of the saturated acids of the oil was prepared for publication. Work is proceeding on the unsaturated acids which were shown to be predominantly C_{18} acids.

(*c*) *Studies on Fatty Acids.*—Studies on the separation and characterization of fatty acids are an essential part of the above project as well as a basic contribution. The work on the partition chromatography of fatty hydroxamic acids was completed and a paper prepared for publication. Some study was made of the unsaturated acids from vegetable oils, as physical properties indicated the presence of minor constituents of unknown structure. A study is being made (in co-operation with the Professor of Organic Chemistry, Sydney University) of reagents other than alkaline glycol for the isomerization of unsaturated fatty acids.

(*d*) *Determination of Ethylene Dibromide in Fruits.*—Following on the publication of a paper for determining ethylene dibromide (used for destroying the fruit fly) in the air of a fumigating chamber, work is proceeding on the determination of this substance in the fruit.

(*e*) *Water-soluble Constituents of Fruit.*—These studies are adding to the general fund of knowledge of the composition of the flesh of several species of fruit, as well as providing basic data for the study of chemical reactions occurring in processed fruit. The techniques developed have also been used to detect amino acids and sugars in materials (e.g., eggs, fish, and freeze-dried bacterial cultures) being studied by other groups in the Division.

Displacement chromatography on columns of strongly basic anion-exchange resins has been used to separate, isolate, and purify water-soluble organic acids. The order of emergence of 27 acids from such columns has been recorded. Using this method, *l*-quinic, succinic, L-malic, and citric acids have been isolated from the flesh of the apricot fruit. Similarly, *l*-quinic, L-malic, and citric acids have been isolated from peach fruit and it has been shown that any one of them may be the predominant acid depending on the variety, season, and maturity of the fruit. Free galacturonic acid has been isolated from peach fruit, but was found only in fruit picked at commercial maturity and ripened at 20° C. This acid has previously been isolated only in glycosidic combination. Mucic acid has been isolated from peaches and pears, this being the first time it has been found in fruit.

The sugars and polyols in a number of samples of apricots, peaches, pears, and apples picked in several seasons were examined by paper chromatography. Xylose, fructose, glucose, sorbitol, a cyclitol (probably *meso*-inositol), and one or more ketose oligosaccharides were detected in all the fruits. Each species of fruit gave a characteristic pattern of spots. More detailed studies were made of the sugars in apricot fruit by means of chromatography on cellulose columns and charcoal columns. This resulted in the detection for the first time in fruit of a series of ketose oligosaccharides.

(*f*) *Chemical Reactions in Processed Fruit.*—The study of browning reactions in freeze-dried apricot and peach purées has been continued. The water-soluble constituents of material stored for fourteen or fifteen months at 25° C. at 20 per cent. moisture content have been studied by means of paper chromatography. The water-soluble basic compounds have been separated by means of displacement chromatography on ion-exchange columns and compared with the free amino acids in the untreated fruit purée.

(*g*) *Protein Physical Chemistry.*—(i) *Protein Denaturation.*—Foods such as milk, meat, and eggs form highly complicated colloidal systems. During their processing and preservation marked changes in their colloidal structures frequently occur. One of these phenomena, protein denaturation, is so important that it has been made the subject of an intensive physico-chemical study. It is concerned with the effect of physical agents (such as heat) and chemicals (such as urea) on pure proteins. This work is being carried out in collaboration with the Biochemistry Department of the University of Sydney and the C.S.I.R.O. Dairy Research Section.

The urea denaturation of bovine serum albumin, ovalbumin, and β-lacto-globulin has been studied by means of sedimentation in the ultracentrifuge, diffusion, optical rotation, and solution viscosity increment. New light has been thrown on the unfolding and aggregation reactions of these proteins and a paper on this work has been submitted for publication.

A separate study is being made of the aggregation reactions of the milk proteins, α- and β-casein.

(ii) *Protein and Amino Acid Metal Complexes.*—Metal complexes of certain amino acids and proteins are being studied by means of polarography and pH titrations in order to get some idea of the strength of binding of the metal in these complexes. In connexion with this work a recording polarograph of new type is being developed in collaboration with the Physics Section.

(*h*) *Infra-red Spectroscopy.*—(i) *Limonin.*—The investigation on the infra-red spectra of limonin (the bitter principle of oranges) and related compounds was continued in collaboration with the Canning Section. The intensity of the carbonyl absorption bands was investigated in an attempt to determine the number and type of carbonyl groups present in these molecules. This work necessitated careful desiccation of the infra-red spectrometer and a technique for this moisture removal was developed.

(ii) *Bicyclo-octane.*—Measurements have been made on bicyclo-octane in preparation for a normal co-ordinate vibrational analysis in collaboration with Dr. I. G. Ross, Physical Chemistry Department, University of Sydney.

4. Microbiology of Foods.

(Division of Food Preservation and Transport.)

The principal aim of these studies continues to be the accumulation of reliable quantitative data regarding the rates of growth and of death of important food-spoilage and food-poisoning micro-organisms. When obtained under adequately controlled conditions, such data can be used to predict the reactions of micro-organisms under the various conditions which might apply in the processing and storage of foods. The laboratory continues to receive a number of problems concerning the diagnosis and control of spoilage in foods.

(*a*) Clostridium botulinum *Investigations.*—Some additional experimental work on the physiology of ten type E strains has been done and the results have been prepared for publication. Some experiments on the water requirements of types A and B strains have also been continued.

(*b*) *Bacterial Spores.*—In spore germination studies the increased sensitivity of heated spores to low concentrations of fatty acids in the germination medium has been confirmed with a study of five acids and seven additional organisms. The results of this and earlier work are being prepared for publication. Some experiments on the metabolic changes during germination were also carried out.

Studies on the nature of heat resistance of spores have concerned the examination of spores, markedly different in heat resistance, for differences in chemical and physical properties. In co-operation with a student of the New South Wales University of Technology a significant correlation was found between the heat resistance of spores and alkali resistance but not acid resistance. Electron micrographs of very thin sections of spores prepared by the Division of Industrial Chemistry have not revealed a relationship between the thickness of the spore coat and heat resistance.

Heat resistance data were obtained and used to evalnate safe processes for canned bananas and baked beans.

(*c*) *Water Relations of Micro-organisms.*—A paper describing the water requirements of a food-poisoning *Salmonella* in relation to the nutritional status of the medium has been published. A further paper dealing with the effects of the availability of water on growth, respiration, and the accumulation of certain

salts by this organism has been accepted for publication. Studies of the water relations of some *Pseudomonas* organisms have been continued and experiments with a species of *Vibrio* have been commenced. Some of the work has been temporarily discontinued during the absence of an investigator on study leave in England.

(*d*) *Freeze Drying.*—This work on the preservation of micro-organisms by drying from the frozen state has increased considerably. Experiments which commenced last year have shown that the mortality during storage is markedly dependent on the water activity during storage and on the nature of the fluid in which the organisms were suspended prior to drying. These early observations also showed that death during storage was increased by certain sugars including glucose and reduced by some amino acids. These findings led to the theory that death in the dry state is due to the destruction of amino side chains on cellular protein and similar molecules by reaction with various carbonyl compounds which occur naturally in cells. Numerous experiments to test this theory have now been carried out and are continuing. Results already available strongly support the theory, and provide a rational basis for considerably increasing the efficiency of drying processes.

Experiments carried out so far have been done with equipment in which the initial drying process was only partially controlled. Equipment which will permit drying to be studied under more closely controlled conditions has now been constructed, and an investigator has been appointed to accelerate the study of this phase of the process.

(*e*) *Canned Ham.*—A paper on the factors affecting the development of the food-poisoning organisms *Cl. botulinum* and *Staph. aureus* in canned hams was read at an international symposium on the microbiology of semi-preserved meats.

5. Meat.

(Division of Food Preservation and Transport.)

(*a*) *Co-operative Investigations.*—The investigations on quality of beef carcass in relation to processing and pre-slaughter conditions, which were carried out in co-operation with the British Department of Scientific and Industrial Research, have been resumed. The present series is aimed at confirmation and amplification of the effects of factors which were shown to have effect on eating quality, or on the extent of drip from thawed beef. The influence of such treatments on the rate of development of micro-organisms will be studied in further detail.

(*b*) *Muscle Biochemistry.*—A comparative study is being made of the post-mortem physical and chemical changes in the muscles of various animals with a view to establishing fundamental information on the nature of drip in beef muscles.

A comparison of the behaviour of whole and homogenized muscles from beef and whale is in progress; two expeditions to coastal whaling stations were made in 1954, and will be continued this season. The very slow rate of post-mortem changes in whale muscle at 35° C. has necessitated measures to retard putrefaction during laboratory operations. Studies with antibiotics have indicated that this may be achieved without significant interference with chemical changes.

(*c*) *Bacteriology.*—The relation which was found between time of development of rigor and the rate of development of micro-organisms on fresh minced ox muscle has not been found with extracts from frozen muscle. With minced fresh and frozen muscle from cracker cows the relationship is more clear-cut than with ox muscle, but there is no relationship with extracts of the muscle. The washed, centrifugal residues left after extraction are now being examined to see if there is any such relationship with this material.

A number of organisms have been selected, identified, and examined for ability to metabolize certain substrates. These organisms are to be used in a study of the mechanism of inhibition of some organisms by carbon dioxide.

(*d*) *Freezer burn.*—Extension of the programme on this subject has shown that when samples are frozen without moisture losses during the freezing stage comparatively high losses before freezing are necessary to prevent freezer burn. Where losses take place during freezing much greater loss must take place in store to produce comparable degrees of freezer burn.

In this work it has been found that a study of the relation of moisture content and fat content of liver is useful in differentiating between livers, and this has made necessary a study of the extractability of fat by various solvents.

6. Fish.

(Division of Food Preservation and Transport.)

(*a*) *Fundamental Investigations.*—Heat inactivation of tyrosinase which is responsible for the development of melanin-like substances in certain tissues of crustaceae has been studied. Loss of salt solubility (denaturation) has been measured in whole fillets and minced flesh from the same fish during frozen storage. Work on the breakdown of urea and of trimethylamine oxide in canning of shark flesh has been completed.

(*b*) *Applied Investigations.*—The uptake of salt by the tail meat of whole crayfish during cooking in salt solutions of various strengths has been measured. The acceptability of crayfish flesh cooked after frozen storage has been compared with that of similar crayfish cooked before freezing. Studies have been made on "fish sticks" prepared from shark flesh. Oil analyses of barracouta have been continued for a further season. Processing studies have been carried out on the canning of tuna, Pacific oysters, Jack mackerel, barracouta, and Australian salmon.

7. Egg Investigations.

(Division of Food Preservation and Transport.)

(*a*) *Pink Whites in Stored Eggs.*—The ingestion by fowls of plants of the family Malvaceae gives rise rather quickly to a pink colour in the white of the egg and to changes in the yolk after cold storage. Since these effects represent an acceleration of the degradation of normal eggs in cold storage, fundamental knowledge about the mechanism involved may assist in the storage of eggs.

Eggs obtained from fowls fed a fatty acid isolated from *Malva* spp. showed a high incidence of pink whites and associated effects after cold storage. Changes in the concentration of several constituents of the egg white were consistent with a possible mode of action of the acid through effects on the permeability of the vitelline membrane or the yolk surface or both.

Some chemical and physical properties of this fatty acid have been determined.

(*b*) *Control of Egg Yolk Colour.*—The addition of a pigment to fowls' diet produced eggs with normal, stable, coloured yolks when the diet was lacking in natural yolk colouring materials.

8. Fresh Fruit and Vegetable Storage and Transport.

(Division of Food Preservation and Transport.)

(*a*) *General.*—The collaboration with the University of Sydney at the Plant Physiological Research Unit, with the New South Wales Department of Agriculture, both at Homebush and at the Citrus Wastage Research Laboratory, Gosford, and with the University of Melbourne, was continued. As in previous years, this large collaborative venture has

resulted in research ranging from academic problems in plant physiology to problems concerned directly with improving storage quality and decreasing wastage.

(*b*) *Plant Physiology and Biochemistry.*—Plant physiological and biochemical research carried out in collaboration with the Universities are designed largely to study the physiological organization of the cell and the biochemical interrelations of different plant processes. Work on the microscopic particles which occur within cells has been continued and their structure has been studied further with the electron microscope in collaboration with the Division of Industrial Chemistry. The study of chloroplasts, the green bodies of the cell, has been extended to include examination of their development. Further work has shown that plant mitochondria have internal particles as well as a surface membrane. The physical properties of the mitochondrial membrane have been examined by electrical techniques, and by the capacity of the particles for absorbing different quantities of sodium, potassium, and chloride ions. Since these particles carry out the chemical reactions concerned in the process of respiration their oxygen absorption has also been studied.

Experiments on the physiology of development in peas have been extended and the interrelations between carbohydrate syntheses, protein syntheses, respiration, and water content have been studied. In addition to providing interesting material for biochemical investigations, this work may contribute to our knowledge of the development of optimum maturity for processing. The peas have also been analysed for changes in the content of the phosphate carriers which are responsible for taking energy, liberated in respiration, to the synthetic processes of the cell.

The change in rate of respiration known as the Pasteur effect, which takes place when living material is transferred from aerobic to anaerobic conditions, has been explained as being due to changes in the concentration of the phosphate carriers. The first experimental proof of this hypothesis has been obtained. The changes in phosphate accompanying the development of the fruit have been examined in apples also, in relation to earlier hypotheses of the control of starch content.

Peas are also satisfactory material for the extraction of the enzymes responsible for the synthesis of sucrose and work on the mechanism of this synthesis has been continued. Enzymes extracted from peas are being used for a study of the respiration process.

The physiology of the development of orange fruits has been studied for more than a year in Valencia oranges. This work is being repeated for a second season and is likely to lead to some hypotheses about how "quality" in oranges is developed.

(*c*) *Technology.*—(i) *Best Conditions for Storage of Apples.*—Most of the work on storage of apples has been concerned with the technique of gas storage, i.e., the method by which oxygen and carbon dioxide in the store are controlled to prolong storage life and improve quality. This technique is now used commercially with pears. These experiments aim at improving the technique further and applying it to apples, particularly the Granny Smith and Delicious varieties.

The effect of rootstock on the keeping quality of Jonathan and Granny Smith apples has been examined, using fruit from the stock trials at the Bathurst Experiment Farm.

(ii) *Best Conditions of Storage of Pears.*—The effects of delay before storage in Williams Bon Chrétien and Packham's Triumph were investigated for several years and led to experiments on the physiology of ripening, particularly on the changes in respiration rate and protein nitrogen content during the ripening processes.

(iii) *Control of Wastage in Citrus.*—The use of sodium orthophenyl phenate as a dip to control mould wastage in oranges has been most successful and has been adopted as a standard practice by the co-operative packing houses of the New South Wales coastal district. Further work has been continued to improve the method still further. The alternative recommended treatment, i.e., wrapping fruits in paper impregnated with diphenyl, has proved satisfactory in commercial trials and the minimum content of diphenyl per wrap has been specified by experiment.

Work on lemon storage has been continued, particularly with experiments using field sprays at critical stages during the development of the fruit, to minimize the fungus which causes stem-end rot. Combination of the appropriate field spray and the post-harvest dip treatment for the fruit suggests that winter lemons may be stored for five to six months without much loss due to stem-end rot.

Work on the development of quantitative methods for determining the fungal spore load of fruits in natural conditions has been continued in collaboration with Dr. T. B. Kiely of the New South Wales Department of Agriculture.

The influence of orchard factors on the keeping quality of oranges has been studied further by comparison of fruits grown under different conditions on Farm Block 466, Griffith (in collaboration with the Irrigation Research Station; *see* Chapter IV., Section 3 (*b*)).

Two important factors have renewed interest in the low-temperature storage conditions for oranges: firstly, the increase in Queensland fruit fly in citrus growing areas of Australia, and New Zealand's requirement that fruit from these areas must be held at low temperature for some days, and secondly, the possibility of extending exports to more distant markets overseas. Considerable variability in the degree of injury has been observed in oranges from different sources stored at or about 32° F. for quarantine sterilization against the fly.

(iv) *Control of Fruit Fly.*—The increase in spread of Queensland fruit fly in eastern Australia has increased the need for post-harvest treatments which will kill the fly in fruits to be sent to markets where some such sterilization treatment is required. While satisfactory fumigation methods have been developed, some further experiments are necessary to assess the danger of injury to the fruit itself, and experiments are continuing on low-temperature treatment and its tendency to injure the fruit.

9. Canning and Fruit Products.

(Division of Food Preservation and Transport.)

(*a*) *Vegetable Canning.*—Pea canning investigations were continued in Tasmania and New South Wales. Work at Devonport consisted of a large-scale crop analysis trial, the chief object of which was to provide samples of peas of known history for detailed chemical analyses by the Plant Physiology Unit. These results may provide a basic explanation for significant changes in maturity previously recorded by the maturometer technique. Sampling was continued over a longer period than in previous seasons in order to evaluate the curve for ripening from the earliest to the latest sampling times within the limits of the maturometer. The curve proved to be quadratic, and it may be assumed that change in direction does not occur until the peas are approaching the seed stage. When considered over the seven days prior to the optimal harvest time the straight-line increase in maturation typical of ripening curves in previous years was obtained. Since this portion of the curve is all-important in maturity prediction, further confirmatory evidence was obtained of the validity of the C.S.I.R.O. prediction technique.

The practice of canning size-graded peas has in recent years been superseded by the ungraded pack from which the overmature fraction has been removed continuously by gravity separation in a quality grader. Some preliminary work has been commenced to compare the relative merits of quality control by mechanical size-grading and by gravity grading, since it is possible, by suitable modification, to use the mechanical grader on the continuous flow principle, instead of by the costly intermittent procedure hitherto adopted.

At Richmond, New South Wales, with the co-operation of the New South Wales Department of Agriculture, investigations into the operation of pea viners were continued. The amount of damage or tenderization of peas as measured by the maturometer increased regularly with uniform increase in viner speed. This result confirms observations made previously in the United States of America.

The efficiency of viner recovery at different speeds was investigated and maximum yield was obtained at approximately 180 r.p.m. Since the rate of change of maturometer reading is about 0.54 per 1 r.p.m. change in viner speed it is suggested that samples should be vined at 170 r.p.m. to reduce errors in the prediction of the harvest date to a minimum, owing to varying tenderizing effects when viners are run commercially at speeds in the range 150-190 r.p.m. Under these conditions the maximum error would be less than half a day in the time of harvest.

Further studies of appropriate harvest maturity for green beans have been conducted, having regard to the adoption of mechanical harvesting for commercial canning crops in Australia. Changes in yield and composition of ripening crops indicate that the alcohol-insoluble solids determination is likely to prove the most useful maturity index of those under investigation. When this point has been satisfactorily determined large-scale trials will be commenced in co-operation with a selected cannery.

Tomato trials were undertaken at two centres in New South Wales to establish a valid technique for the comparison of canning and pulping varieties. An attempt will be made to compare the varieties tested by summation of selected factors over the whole of the yielding season.

(*b*) *Fruit Canning.*—Work with apricots and peaches previously described was continued. Confirmation was obtained of the ability to hold Trevatt apricots satisfactorily for four weeks at 32° F. An attempt to determine the influence of crop size in a tree stripping and ripening trial was ineffective because the fruit was harvested in an immature condition. This experience further highlights the pressing need for some physical means for the rapid assessment of maturity to replace personal judgment upon which the present work is dependent. A fruit pressure tester has been designed and constructed for this purpose, and it is proposed to accumulate data on its performance in the coming season.

Major problems in solid-pack canned apples now appear to have been solved and recommended procedures have been adopted by Tasmanian canners, whose pack now compares favorably with corresponding grades of overseas packs. The work is being prepared for publication.

Further data have been accumulated in relation to quality specification of berry pulps. Varietal trials with canned raspberries, combined with tests on various syrup strengths, have been completed.

Procedures for improvement of colour and flavour of canned winter pineapples were investigated in co-operation with the Department of Commerce and Agriculture and the Committee of Direction of Fruit Marketing. The use of heavier syrups gave a decided improvement in flavour and one of the techniques for colour improvement showed promise. Further work will need to be undertaken.

(*c*) *Fruit Juices.*—Investigations on the effects of rootstocks on the occurrence of bitterness in canned orange juices have now been conducted during five seasons. Rootstocks for Navel oranges may be grouped as follows according to their influence on bitterness: Tangelo, Cleopatra Mandarin, and *Poncirus trifoliata* stocks give the least bitter juices; Sweet Orange stocks give juices of intermediate bitterness; and Rough Lemon and various Lime stocks give the most bitter juices. With Valencia oranges, only three rootstocks were studied and the order of increasing bitterness in the processed juices was *Poncirus trifoliata*, Sweet Orange, and Rough Lemon. The level of bitterness in Valencia juices is generally lower than in Navel juices, but canned Valencia juices from Rough Lemon rootstocks may be significantly bitter at the peak of the season in October-November.

Chemical studies on limonin, the bitter principle of oranges, have progressed to a stage where it is possible to set out a tentative formula for the compound. It appears to consist of a saturated naphthalene nucleus to which are attached two stable lactone rings and three cyclic ether or acetal groups.

(*d*) *Container Investigations.*—Investigations on the relation between colour loss and iron pick-up in lacquered cans containing beetroot were continued, using test packs of acidified beetroot in place of the previous acidified extract of beetroot-tissue test medium.

The effect of different initial oxygen contents, resulting from variations of vacuum and headspace levels, on the production of hydrogen gas is being studied, using test packs of acidified beetroot. Early results indicate that a high initial oxygen content gives an increase in the amount of hydrogen produced from the corrosion reaction over a given storage period. This result explains some earlier observations during examinations of hydrogen swells which indicated that some factor other than the difference in initial vacuum levels alone was contributing to hydrogen swell formation in highly corrosive products packed in lacquered cans.

Several new lacquers were found to have very good resistance to both acid- and sulphur-staining products, and show promise as universal can lacquers. There are several difficulties associated with the application of these lacquers which at present restrict their commercial use on a wide scale. In co-operation with the Commonwealth Canmakers' Association, test packs have been made to investigate the performance of electrolytic tinplate of 1 lb. per base box in containers for Australian canned foods. It is expected that this plate in the form of "differential tinplate" will ultimately replace most of the currently used hot-dipped tinplate of 1.25 lb. per base box, with consequent reduction in tin consumption, and hence in the cost of tinplate containers.

Changes in vacuum levels in test packs are being followed by a specially designed external can vacuum tester, a novel feature of which is its end-point indication. A provisional patent for the instrument has been obtained.

10. Dehydrated Foods.

(Division of Food Preservation and Transport.)

(*a*) *Vegetables.*—Processing factors relating to the dehydration of green peas are well established but few data are available on factors affecting storage life. Consequently experiments were commenced to provide information on the effects of moisture level and gas packing.

The reconstitution of some dehydrated peas is adversely affected by the lack of permeability of the dried skin. Processing treatments to make the skin more permeable to water have been begun.

A method of processing recently tested in the United States of America involves initial partial dehydration followed by freezing. This method—"dehydrofreezing"—has been tried by using green peas and sweet corn and has been found to be satisfactory.

(*b*) *Fruit.*—Experiments dealing with the factors affecting the uptake of sulphur dioxide gas by cut fruits before dehydration were continued. Information has been obtained on the effects of varying temperature in the sulphuring chamber, air movement over the fruit, and the skin as a barrier to sulphur dioxide penetration. Additional data have also been collected on the effect of size, variety, maturity, and storage factors. Apricots, freestone and clingstone peaches, and pears have been used in the trials.

At the request of prune-growers' organizations, experiments have been commenced on methods of prevention of mould growth in prunes of high moisture content. These involve the use of epoxides as fungicides in sealed "moisture-proof" bags. The chief factors needing study are (i) concentration of fungicide, (ii) moisture level, and (iii) type of container.

Apples are normally dried in kilns in Tasmania. Recently requests have been made from that State for information on improved processing methods and types of dehydrators suitable for drying this product.

(*c*) *Meat Dehydration.*—(i) *Dehydrated Mutton Mince.*—With improved processing and packing techniques storage studies are of necessity of a long-term nature extending over periods of two to three years. For this reason some of the storage experiments described in previous Reports are still in progress. Included in this group are two experiments, one designed to obtain a measure of the effects on quality of different levels of oxygen in gas-packed material, and the other designed to determine the effects of certain flavouring additives incorporated in the packs.

Different types of deteriorative changes take place in dried meat during storage and an attempt has been made to limit one type of deterioration by treating the meat prior to packing with sulphur dioxide. The first storage examination has not been made yet.

(ii) *Dehydrated Beef Mince.*—The aim of these investigations is to determine whether processing and packing techniques developed for dried mutton mince apply equally well to beef dehydration.

11. Frozen Fruits and Vegetables.

(Division of Food Preservation and Transport.)

Investigations on the freezing of fruits and vegetables and the storage of fresh fruit are conducted jointly by the Division of Horticulture, Department of Agriculture, and the C.S.I.R.O. Division of Food Preservation and Transport.

(*a*) *Peaches.*—Results of experiments on freestone peaches suggest that an ascorbic acid level of 150 mg. per 1-lb. pack is sufficient to prevent serious browning. A lower concentration of 75 mg. per 1-lb. pack was intermediate in effect between the 0 and 150 mg. levels. There appeared to be no advantage in using a concentration higher than 150 mg. per 1-lb. pack. These results are based on three varieties of peaches, grown in one season only, and therefore must be regarded as tentative.

(*b*) *Apricots.* — Further information has been obtained on the amount of sulphur dioxide necessary for a satisfactory product. Initial concentrations of 75-100 p.p.m. for syrup-type packs and 25-30 p.p.m. for dry sugar-type packs are suggested. Dipping procedures to give various levels of sulphur dioxide have been determined and apparent losses of sulphur dioxide during freezing, storage, and thawing have been studied.

(*c*) *Pineapples.*—Sugar is commonly added, either as syrup or as dry sugar, to fruits before freezing. The results of several years' experiments suggest that, with pineapple of the correct maturity, the addition of sugar is not essential for the maintenance of good quality during storage. The overseas market, however, still appears to prefer the sugar-packed fruit.

(*d*) *Berry Fruits.*—Tests of varieties and methods of packing berry fruits for freezing have been continued. The raw material has been supplied by the Tasmanian Department of Agriculture and the Organization's Tasmanian Regional Laboratory.

(*e*) *Peas.*—The problem of deterioration in raw peas between "vining" and processing has been further investigated. It is now possible to estimate the probable degree of deterioration occurring during different periods of delay and to suggest the extent to which this can be checked by the use of "pre-cooling".

Maturity studies in a commercial plant have provided useful data on the evaluation of quality-control methods. Samples collected will be used for further work on the determination of optimum maturity of frozen peas.

(*f*) *Sweet Corn.*—Investigations to determine the most desirable stage of maturity are still in progress. From recent work, it appears that the moisture content should be close to 75 per cent. for best quality. The effects of blanching whole-kernel corn on and off the cob have been compared and the influence of washing corn after blanching and of freezing in the loose form has also been studied.

(*g*) *Freezing Rates.*—Some studies of freezing rates of vegetables frozen in an air-blast freezer have been made.

(*h*) *Packaging.*—Tests of several flexible plastic materials as packages for frozen vegetables are still in progress.

12. Wine.

(Oenological Investigations, Waite Agricultural Research Institute.)

The investigations directed by the Committee on Oenological Research are carried out at the Waite Agricultural Research Institute and are concerned with technological problems of the wine industry and improving the quality of Australian wines.

The present investigations comprise a study of the treatment of wines with ion-exchange resins and a continuation of the work on bacterial changes occurring during the maturation of table wines.

(*a*) *Wine Yeasts.*—The work on this subject has now been concluded and is in the course of publication.

(*b*) *Treatment of Wines with Ion-exchange Resins.*—This work was undertaken in an endeavour to prevent the precipitation of potassium bitartrate in wines after bottling, and to study the other effects of such treatment. This precipitation is one of the major problems of the industry and the current method of treatment requires large-scale refrigeration which is very expensive. The work was successful and a method of treatment was developed which prevented precipitation and did not adversely affect flavour. The cost of the treatment is approximately 5 per cent. of the cost of refrigeration. A patent application has been made for the process. Some wines which contained too much acid have been treated with appropriate deacidifying resins and have been greatly improved in flavour as a result. Ion-exchange treatment also caused significant reduction in the metal content of wines, but a greater reduction than that obtained would be desirable. Some of this work was carried out in co-operation with commercial wineries and it is likely that ion-exchange treatment will be adopted commercially.

(*c*) *Malo-lactic Fermentation.*—The cultures previously isolated were tested for their ability to bring about the fermentation in wines of differing acidity, and further wines were examined for the presence of the fermentation.

13. Dairy Products.

(Dairy Research Section.)

(*a*) *General.*—Projects which have made particular progress during the year include those on the creation of new food forms for the nutritionally valuable non-fat solids of milk, studies on the flavour chemistry of dairy foods, and cheese starter investigations.

At the end of the year the Section is in process of moving into the new laboratory and pilot-plant buildings at Highett, Victoria. A major acquisition has been a 400-tube freeze dryer, which has permitted the preparation of cheese starter cultures for distribution by State Departments of Agriculture to cheese factories throughout Australia.

A technical communication on *The Fat Globule Membrane,* written by Dr. King at the request of the Bureau of Dairy Science, has been published.

Talks were given by officers of the Section to scientific and technical meetings in four States. A demonstration of the work of the Section was given at the Better Foods Exhibition held in Melbourne in January.

Research on milk proteins at the Faculty of Agriculture, Sydney University, has been given financial support.

Close co-operation has been maintained with State Departments of Agriculture, with the Queensland Butter Marketing Board, with many dairy manufacturing companies, and with the major dairy engineering firms. The assistance given in many ways by these organizations is gratefully acknowledged.

(*b*) *The Utilization of Skim-milk Solids.*—The special form of milk powder possessing some of the properties of egg-white has been produced under commercial conditions in batches of several tons. The product is now being marketed for use by the pastry-cooking trade and in the household. The milk powder for use in sponge cakes was further improved and adapted to large-scale production by replacing the carbonate mixture in the second stage with phosphate buffer solution. Baking trials with equipment used in wholesale cake manufacturing are giving very satisfactory results.

Several aspects of the processes used in making these special milk powders are proving of scientific interest. The Maillard reaction between casein and lactose has been found to take place during the treatment of concentrated skim milk with lime, and to be detrimental to the quality of the meringue powder. Viscosity curves for both calcium hydroxide and sodium hexametaphosphate treatment of milk concentrate pass through a maximum, and the role of lactose in these reactions is being investigated.

(*c*) *Stability of Vitamin A in Non-fat Milk Powder.*—The dietetic value of non-fat milk solids both in Australia and in the Asiatic countries is little inferior to that of whole milk. The main difference is in the vitamin A content, and if this deficiency were corrected non-fat milk solids would become an even more valuable food at extremely low price. Synthetic vitamin A is now readily available, but the problem is to add it to the milk powder in such a way that it will not be lost by oxidation during storage. By using hydrogenated coconut oil as a vehicle and adding edible antioxidants, a very stable condition of the vitamin A has been achieved: after six months at 40° C. more than 90 per cent. of the vitamin remains. The methods are being applied in commercial-scale tests.

(*d*) *Oxidation Defects.*—Continuation of the investigation of the chemical compounds responsible for oxidized flavour in milk has clarified the importance of the 2,4-dienals. Decomposition of some 2,4-dinitrophenylhydrazones has been found to take place on silicia adsorption columns.

When ascorbic acid is added to washed cream a strong oxidized flavour develops. This has been found to take place without peroxide formation in the fat.

A de-emulsification technique has been developed for rapidly and simply obtaining the fat from milk and cream for determination of its peroxide value.

A defect in the nature of a fishy flavour which devolops in some samples of butter fat when treated with an antioxidant (nordihydroguaiaretic acid) and citric acid in propylene glycol is being investigated.

(*e*) *Structure of Dairy Products.*—The state of dispersion of the fat in condensed milks was investigated by means of fluorescence microscopy. A method of differential staining with fluorescent dyes was elaborated for milk powders, permitting an insight into the distribution of the fat in the powder particles as affected by different manufacturing processes, and by conditions of storage. The dye acridine orange was found to give a double fluorochroming in milk, the fat showing a green and the protein an orange fluorescence.

Observations were made of the microstructure of "instant soluble" milk powders, and of the detailed mechanism of milk reconstitution. Alcohols were observed microscopically to provoke crystallization of the lactose in dried milks.

(*f*) *Cheese Starters.*—A lysogenic strain of *Str. lactis* in successful commercial use for some time was attacked in turn by two new phage races. The study of the host-phage relationship of this strain, and its related forms, led to important observations on the production of bacteriolytic enzymes at the time of lysis by phage. These lysins affect heterologous strains, and the phenomenon must be considered in all studies on the compatability of bacterial strains for use in cheese starters.

New strains of heat-tolerant lactic acid bacteria suitable for use in the short-time cheese-making process are being sought.

(*g*) *Cheese Manufacture.*—Studies on the new method of cheese manufacture have been directed to the influence of pH and moisture in the cheese after pressing on the subsequent ripening of the cheese; to the role of the ordinary starter and of *Str. durans* in controlling pH; to the optimum cooking temperature; to the retention of calcium salts and of lactose; and to the precise treatment to which the curd must be subjected to give the desired physical properties. The latter information is needed as a basis for the studies on the mechanization of the process which are now proceeding.

(*h*) *Milk Drinks.*—Information has been collected and technical improvement sought in the field of flavoured milk drinks, malted milk (particularly froth stability), homogenized milk, and reconstituted milk.

(*i*) *Total Solids Determination.*—The reliability of the specific gravity and fat test as an index of the total solids content of Australian milks is under investigation.

(*j*) *Miscellaneous.*—Other technical and scientific matters which have been given attention include the use of detergents in fat estimation: the "acid-amide" test for casein; solubility and dispersibility of milk powders; and public acceptance tests of reconstituted milks.

14. Dried Vine Fruits.

(Commonwealth Research Station, Merbein.)

For the 1955 harvest several large-scale trials of the commercial oils used for the cold dipping of sultanas showed that all oils possessed similar drying rates and produced fruit of the same quality.

Trials were made at Woorinen on the hot sulphite dip to determine the effect of the alkali concentration of the dip and the temperature of dipping on the storage qualities of the fruit, particularly with respect

to stickiness and sugaring. A surprising result was that a boiling dip of low caustic soda concentration did not severely crack the skin of the fruit as expected and gave very even and rapid drying with extremely good mould control.

Since 1951 it has been recommended that the alkalinity of the cold dip for sultanas should be maintained by the addition of caustic potash to give a faint blue colour with a thymolphthalein test paper. Weight trials made this season showed that the drying capacity of the dips is independent of the pH of the dip. This work also indicated that thymolphthalein papers do not give the true pH of the dip so that the use of indicators in solution may be necessary.

The 1955 harvest was noted for the large amount of damage done to crops by mould. It was found that sodium sulphite in small concentrations had no beneficial effect in mould control in sultanas. Under the conditions of experiment, mould was confined to the damaged fruit and did not spread under warm conditions even if humid.

Based on previous laboratory experiments some trials were done on the dipping of gordos with the object of determining the effect of potassium and sodium compounds and dipping oil on the deseeding qualities of the dried fruit.

Fundamental physico-chemical studies have been started to determine the mechanism of the drying process. Drying experiments in a special apparatus designed to provide controlled conditions of temperature, humidity, and air-flow rate, show that the complete drying of a grape occurs in three distinct stages for each of which there is a linear relationship between time and the logarithm of the water content of the grapes. The first discontinuity occurs at roughly 30 per cent. loss in weight, corresponding to the stage where the overall elastic contraction of the skin ceases and the skin wrinkling begins. The second discontinuity occurs at the stage where moisture content of the grape is about 23 per cent. Experiments on peeled grapes indicated that the water movements within the grape during drying are fast relative to the transfer through the skin.

Experiments in which sultanas were treated with petroleum ether to remove the cuticle and then dipped in aqueous solutions of surface-active agents indicate that such agents incorporated in dips act mainly as emulsifying agents.

XIV. FOREST PRODUCTS.

1. General.

Australia is not a heavily forested country, although a wide range of eucalypts and other species of timber is available. Full and proper use of existing timber resources is therefore essential, and this can only be achieved with the aid of fundamental data on the properties, potentialities, and correct methods of treatment of our timbers.

The Organization's Division of Forest Products, with its laboratory in Melbourne, was formed to carry out investigations on Australian forest products and to give direct assistance to all concerned in the utilization of forest resources. Its work is directed toward the more effective use of those resources, by reducing waste in forest, mill, and factory; by reducing losses from decay and insect attack; and by improving the quality of timber produced in the growing forest by the study of the relationship between silvicultural treatment and timber products. The work of the Division is reported in this chapter. Some work on timber pests is undertaken by the Division of Entomology (*see* Chapter IX.).

Division of Forest Products.—Wood-using industries have continued to operate at a high level during the year. There has been an appreciable increase in inquiries and these reached the record figure of 9,000. Visitors to the Division also increased by approximately 20 per cent. to 1,900. Inquirers have shown particular interest in timber from countries north of Australia. These tropical timbers, representing a great number of species, are likely to be imported into Australia in increasing quantities to meet the deficiency between local supply and demand. Australia is a logical market because, in addition to its geographical position, it is predominantly a hardwood-using country and is well experienced in using timbers with similar properties probably for a wider range of uses than any other country.

The Division lost another officer of wide experience in Mr. Alan Gordon, Officer-in-charge of the Veneer and Gluing Section, who left to take a senior position with a New Zealand company. He was also Executive Officer of the Wooden Case Research Committee. This loss, with the transfer of some officers to more fundamental work, has left the Division vulnerable on the applied side, and it has been only with the greatest of difficulty that all urgent demands for work in this field have been met. Such applied problems have included the kiln drying of timber and veneer and the design of suitable kilns, the preservative treatment of klinki pine in New Guinea, tannin extraction from mangroves, tannin formaldehyde adhesives (in conjunction with the Division of Industrial Chemistry) and sawmill design.

The demonstrations on the preservative treatment of fence posts have continued and are arousing increasing interest.

The Wooden Case Research Committee has been in operation during the year and research with contributions from industry has been continued. It was hoped that this work would lead to the industry taking greater responsibility for its own research.

During the year a committee was set up with representatives of pole-using authorities, for forest service, and the Division, to study the need for experimental work on the design of poles. The committee considered that work was urgent and a working plan has been prepared and approved.

The Chief of the Division, Mr. S. A. Clarke, visited New Guinea in August, 1954, and was a delegate to the Third Session of the F.A.O. Asia-Pacific Forestry Commission held in Tokyo in April, 1955; Dr. H. E. Dadswell, Assistant Chief of the Division and Officer-in-charge of the Wood and Fibre Structure Section, was official Australian delegate to the VIIIth International Botanical Congress, Paris, July, 1954. Mr. H. G. Higgins of the Wood Chemistry Section left during May for a visit overseas, and attended the Conference of German Technical Association of Pulp and Paper Chemists and Engineers at Baden Baden.

Overseas visitors included timber scientists from England, New Zealand, United States of America, and Indonesia; and a number of students and Fellows from overseas were working in the Division during the year.

The Timber Mechanics investigations at the Engineering School of the University of Western Australia have been continued, although hampered by the difficulty in obtaining research staff. For some time the work of the Wood and Fibre Structure Section has given leads to desirable physiological investigations. Recently arrangements have been made for physiological studies, particularly related to the formation of tension wood, to be carried out in collaboration with the Botany Department of the University of Sydney.

The Fourteenth Pulp and Paper Co-operative Research Conference was held at the Division in November, 1954, with a strong representation of technical men from the four paper companies which make financial contribution to this work.

The correspondence courses in seasoning were continued; a seasoning class was held in Adelaide in co-operation with the Timber Development Association;

and courses of study at the Division were given to forestry students. The Forest Products News Letter which reports technical progress in popular language was issued at regular intervals.

Courses of lectures were given to students of architecture, forestry, building science, industrial management, and land surveying, and to engineers of the State Electricity Commission, Victoria, and individual lectures to branches of A.P.P.I.T.A., to the Institute of Foresters, to the Junior Chamber of Commerce, and to school groups, &c. In addition several broadcasts and demonstrations were given and organized parties were shown over the Division.

A pleasing feature of the relationship of the Division with industry has been the way in which firms and individuals have expressed their appreciation of help given, by contributions to the funds of the Division. These miscellaneous contributions totalled £2,000 for the year.

The help and co-operation of the paper companies, the wooden case industry, the Commonwealth Forestry and Timber Bureau, the State Forest Services, the New Guinea Department of Forests, and of all other branches of the timber and allied industries, are gratefully acknowledged.

2. Wood and Fibre Structure.

(Division of Forest Products.)

(*a*) *Anatomical Investigations.* — (i) *Wood.* — Of interest has been the examination of specimens of *Nothofagus* from New Caledonia, collected by one of the officers of the Division during a recent visit. The anatomy of these compared almost exactly with that of the New Guinea representatives of the genus, thus supporting the botanical evidence. Work on timbers of the Flacourtiaceae and Cunoniaceae from the south-west Pacific area has been completed and is being prepared for publication. The next families in this series being studied are the Burseraceae and Sapindaceae.

(ii) *Bark.*—The collection of 1,576 specimens of 275 different species of the genus *Eucalyptus* has been the basis of a very comprehensive study of eucalypt bark anatomy, covering species in the bloodwood, peppermint, box, ironbark, and stringybark groups; and those species with oil glands and with radially elongated phelloderm. The anatomy of bark has been found of particular advantage in the investigation of hybrids of which some 42 have so far been examined.

(*b*) *Identifications.*—From trade sources, individuals, and various Government departments throughout Australia, some 700 timber specimens were examined and identified during the year. Also over 800 specimens of New Guinea timbers were examined to assist botanical determinations of material collected by the C.S.I.R.O. Land Research and Regional Survey Section. In connexion with a survey being carried out by the Section of Wood Preservation, some 100 house stumps have so far been identified. Several additional copies of the card-sorting key for the identification of families or family groups have been prepared for other laboratories.

(*c*) *Tension Wood.*—The extensive structural investigations of tension wood fibres already carried out and reported have formed the basis for the examination and explanation of many of the abnormal and often undesirable properties of tension wood. Thus it has been observed that the collapse of tension wood on drying is often associated with abnormally high shrinkage of the thick, unlignified cell walls. Considerable stresses are developed, resulting in the rupture of the intercellular layer. Whereas the collapse in normal wood can be overcome by suitable reconditioning treatments, that in tension wood is irrecoverable. This may be due in part to the absence of an inner layer to the cell wall as found in the normal wood fibre.

Further, the reduced lignification of the intercellular zone, as revealed both by staining techniques and the use of ultraviolet microscopy, has suggested that tension wood fibres may be easily separated by mechanical treatment of fresh wood. Laboratory tests have proved that this does occur, a fact of some importance in considering the reasons for good and poor grinding qualities of certain timber. In view of the economic importance of tension wood, various field experiments have been set up to investigate factors governing its formation and function in the growing tree. Preliminary observations have shown that the stimulus responsible for tension wood formation proceeds downwards in the stem, and support the theory that hormonal influences are associated with its development.

(*d*) *Cell Wall Texture.*—Some five years ago it was suggested that each micelle was surrounded by a paracrystalline phase of cellulose. More recently evidence for the presence of this phase was forthcoming from the observed increase in the apparent crystal (micelle) size on dilute acid hydrolysis. It was found that some increase in apparent crystal size takes place during the preparation of holocellulose, and further that the increase in hydrolysis is greater in the case of holocellulose than in the case of the original wood. It would thus appear that some of the amorphous cellulose is in fact paracrystalline and closely associated with the lignin and hemicellulose. It is possible that the fractions of lignin and hemicellulose which are removed only with difficulty in the holocellulose preparation are those which are associated with the paracrystalline cellulose. It was observed when comparing cellulose of normal wood with that of tension wood that (i) the apparent crystal size is less in normal wood than in tension wood, (ii) the increase in apparent crystal size on hydrolysis is less in tension wood than in normal wood, (iii) the intermicellar spaces as indicated by the size of crystals deposited in the sample are the same in normal wood and in tension wood, and (iv) the moisture regain is less in tension wood than in normal wood. These investigations thus provide a physical interpretation of concepts such as the crystalline/non-crystalline ratio. In more recent work examples have been obtained in which it appears that the cellulose exists wholly in the paracrystalline condition.

(*e*) *Surface Structure of Wood Fibres.* — The changes in structure of wood fibres during beating have been studied, using the techniques of surface replicas, of sectioning of paper sheets, and of shadow casting in conjunction with optical microscopy. During the beating of hardwood fibres in the Lampen mill there is a rapid accumulation of primary wall material in the early stages, such material coming from vessel elements as well as fibres and from fragments of parent walls.

(*f*) *Growth in Plant Cells.*—It has been previously shown that, in the formation of wood fibres, surface growth proceeds in length at the cell tips and in breadth at centres over the cell surface—the regions of the pit fields. A similar mechanism had also been proposed for parenchyma cells, but investigation has shown that during extension growth the pit fields tend to remain constant in number and to separate during extension. This change is accompanied by an increase in the dispersion of microfibrils between the pit fields so that to some extent the cell wall appears to be stretched during extension.

(*g*) *Bark and Wood Extractives.*—From analysis, it appears that the leucoanthocyanins in eucalypts originate in the tips of young leaves and are transported down the phloem through the cambial region

into the wood of the tree. At the sapwood-heartwood boundary the amount of these compounds decreases. It is considered that the leucoanthocyanins may be the precursors of tannin and related substances occurring both in bark and wood; the change is apparently initiated at the sapwood-heartwood boundary. Work is being continued to prove or disprove this hypothesis.

A survey of the tannin content in the bark of various mangrove species has been carried out for the New Guinea Forests Department. The eucalypts of the semi-arid zone of Western Australia were investigated with respect to yields of tan-bark, in order to stress their value in any reafforestation programme. Assistance has been given to a firm manufacturing tannin extract (cutch) from the mangrove bark, collected in the Delta region of Papua. An officer of the Division gave advice on the operation of the plant and suggested modification to meet varying climatic conditions. Apart from its normal industrial uses the cutch is being investigated as a raw material for the manufacture of an inexpensive plywood adhesive.

3. Wood Chemistry.

(Division of Forest Products.)

(*a*) *Lignin and Related Compounds.*—The residual lignins of pine pulps have been investigated by determination of their principal oxidation products. The ultraviolet absorption spectra of eucalypt and pine pulps in phosphoric acid have also been studied. None of the results indicated any difference between the residual lignin and the lignin of the original wood. The difficulty of removing the last traces of lignin from the pulps appears to be one of accessibility.

Initial experiments with the recently constructed 50-tube, automatically controlled, Craig machine have shown that purification of lignin by a counter-current distribution method is feasible. However, a solvent system giving a satisfactory differential rate of migration between lignin and the impurities has not yet been found. The value to lignin research of a lignin of proven purity justifies the use of this method even if it proves to be time consuming.

(*b*) *Wood Polysaccharides.*—Extension of chlorite holocellulose from *Eucalyptus regnans* with 5 per cent. sodium hydroxide at room temperature removed most of the non-cellulosic polysaccharides in a short time (5–10 minutes). Both holocellulose and pulps retained about 3 per cent. of pentosans resistant to 5 per cent. alkali. Prolonged treatment resulted in slow dissolution of the resistant non-cellulosic polysaccharides according to an apparent zero order reaction. Alkali extraction of residues from wood cooked with methanol at 150° C. indicate that resistant non-cellulosic polysaccharides were liberated by an apparent retarded first order reaction during the methanol treatment, which is supporting evidence for the existence of an association between lignin and these polysaccharides.

(*c*) *The Mechanism of Delignification.*—The percolator has been redesigned and rebuilt and an investigation of pulping reactions at sustained alkali concentration has been undertaken. The rate of removal of lignin and pentosan from *E. regnans* wood at 150° C. has been followed at different concentrations of sodium hydroxide and different flow rates. The amount of pentosan removed depended mainly on the total amount of alkali used but the removal of lignin depended mainly on the concentration of alkali. The pulping reactions proceeded more rapidly in the percolator than in sealed bombs at the same initial alkali concentration.

(*d*) *Pulping of New Guinea Woods.*—Pulping of mixtures of woods of the mangrove association has been extended, the sulphate process being used. The properties of the papers produced could be changed by varying the quantities of the different woods in the mixture. Pulps produced from the *Araucaria* spp. by the sulphate process were bleached according to conventional commercial procedures. Rectangular sheets formed on a hand mould were used for printing cards giving some general information on the pulping and paper-making properties of these timbers. The exceptionally high tearing strength of these cards has attracted considerable interest from manufacturers of fine papers.

(*e*) *Semi-chemical Pulping of Eucalypts.*—Little information is available on the yields and properties of semi-chemical pulp made from eucalypts. The cold soda process, in which the wood chips are soaked in cold alkali and then mechanically defibred, has been investigated. Soaking for 24 hours in cold 2 per cent. sodium hydroxide gave after defibration an 80–85 per cent. yield of light-coloured pulp which had strength properties slightly superior to those of first-quality groundwood.

(*f*) *Influence of Hemicelluloses on Pulp Properties.*—It has been generally considered that the lower strength properties of pulps from which the hemicelluloses have been removed by alkaline extractions are due to the hemicelluloses enhancing beating and thus giving better strength development. It has been shown with eucalypt sulphate pulps that extraction of the hemicelluloses either before or after beating has similar effects in sheet properties mainly because of reduced fibre bonding. Their effect on beating appears to be of secondary importance.

(*g*) *The Pulping of Tension Wood.*—Tension wood and normal wood from one tree of *Eucalyptus goniocalyx* were pulped by the soda process. Although the tension wood was much lower in lignin than the normal wood, it required similar pulping conditions to defibre the chips. Pulp yield was much higher, being 67 per cent. for the tension wood compared with 51 per cent. for normal wood. The tension wood chips did not swell when cooked. Pulp from the tension wood gave handsheets with much lower strength properties than those from the normal wood. Chips from the tension wood could be mechanically defibred to give a reasonable grade of pulp. Normal wood under the same conditions was reduced to a coarse sawdust.

(*h*) *Rheological Properties of Paper.*—The relationship between the shape of the stress-strain curve and the basic structure of the fibre network in the paper sheet has been investigated in the Division's rheometer. The variation in strength properties with change in relative humidity shows some similarity to the cellulose-water sorption isotherm. Tearing tests have also been carried out on the rheometer, and these have been compared with the results obtained with the more conventional tear-testing instruments and with the other rheological properties of the paper.

(*i*) *The Mechanism of Beating.*—The removal of fine material greatly increases the efficiency of the beating process. It is considered that this is due to the lubricating effect of the fine material in the beater, which reduces the amount of effective work done on the unbeaten fibres. The strength of a sheet formed after readdition of removed fines to the coarse fibre fraction is less than that of a sheet made from the original unfractionated material.

(*j*) *Adhesion within Paper Sheets.*—The rheological properties of paper made from chemically modified (acetylated) cellulose have been used to study the relative contributions of hydrogen bonding and of swelling and associated phenomena to the strength of the fibre assemblage. Results indicate that hydrogen bonding plays the major role in normal sheet formation, although under special circumstances swelling may become the controlling factor.

(*k*) *Cellulose Reactivity.*—The kinetics of some heterogeneous reactions of cellulose have been studied, and the results indicate a possible relationship between

reactivity and the surface condition and degree of crystallinity of the solid cellulose. It appears that these properties may be related to the inter-fibre bonding potential of the cellulose.

4. Timber Physics.

(Division of Forest Products.)

(*a*) *Sorption Studies.*—Direct measurements of the heat of wetting of wood (sawdust) have been made using an adiabatic calorimeter constructed within the Division. Measurements were made at 26, 36, and 46° C. on samples whose initial moisture contents varied from zero to 24 per cent. The heat evolved on wetting decreased with an increase of temperature, thus confirming earlier predictions based on the variation of specific heat with moisture content. Measurements of heat of wetting are now being extended to include materials such as lignin and wood cellulose. Sorption cycles between zero and 99 per cent. relative humidity have been completed at two temperatures (25 and 40° C.) for matched samples of klinki pine. It was confirmed that the equilibrium moisture content at any given relative humidity was lower and the width of the hysteresis loop smaller at the higher temperature. These two experiments have been used to estimate the variation of the more important thermodynamic functions with moisture content. The differential heat of sorption has been calculated from the measurements of the heat of wetting, the change in Gibbs function from the isotherm determinations, and the change in entropy from the combined results of the two experiments.

(*b*) *Shrinkage and Density Measurements.*—Dimensional stability tests have been carried out for a wide range of commercial hardboards and similar tests have been commenced for insulating boards. Considerable variation in equilibrium moisture content and thickness swelling was observed between different makes of hardboards, but variation in length swelling was much less. It was found that the thickness tends to increase and the length to decrease on repeated cycling over a range of humidity. Shrinkage and density measurements have been continued on a number of Australian species. Tests have been completed on material from 250 trees, representing 82 different species. A large proportion of this material came from less common North Queensland species, for which no data had previously been available.

(*c*) *Creep and Related Phenomena.*—(i) *Applicability of Boltzmann's Superposition Principle.*—Further tests have been conducted to compare creep at constant stress with stress relaxation at constant deformation. In dry wood at 50° C. the relation between creep and relaxation was, as expected on the basis of the linear theory, approximately reciprocal. In green wood at 25° C. the relation departed from linearity, creep being higher than calculated from relaxation. This departure, in contrast to the non-linearity in reaction wood (compression wood), was caused by the recoverable component of deformation. Linearity of rheological behaviour has in addition been investigated by means of superposition tests on air-dry wood in shear. The results showed that linear superposition did not hold during the first few hours after a change of stress, but confirmed its applicability after longer times. The stress in this experiment varied stepwise and was thus essentially different from the stress variation in the relaxation experiment. The results were therefore not fully comparable. However, taken together, they give a reasonable indication of the accuracy to which the response to any applied series of loads can be calculated.

(ii) *Creep and Recovery Measurements.*—Twenty-seven beams of green blackbutt have been loaded for a period of six months and the proportional increases in deflection were found to be similar to those obtained for mountain ash. Measurements of the recovery of air-dry beams of mountain ash after long periods under load have shown that approximately 40 per cent. of the time increment of deflection is due to plastic flow. Recovery measurements have been made on green and dry specimens of mountain ash which had been subjected to tensile stresses for three years, and on dry specimens which had been subjected to compressive stresses for the same period. The residual strains have decreased by as much as 30 per cent. in periods of up to 12 months and are still decreasing.

(iii) *Factors Affecting Creep.*—The effect of stress on creep in tension has been observed and tests showed that the irrecoverable creep increased more than proportionally with stress.

Small-scale beams have been tested under controlled conditions of temperature and humidity to determine the effects of stress and duration of loading on the recoverable and irrecoverable proportions of the time increment of deflection. The beams have been unloaded and recovery is nearing completion. A pilot experiment on the influence of temperature and moisture content on the creep of wood in shear showed a great increase in irrecoverable creep due to interaction of high temperature and high moisture content and an apparent relative independence of the recoverable creep component under the conditions of temperature between 0 and 50° C. and of moisture contents between 5 and 18 per cent. Further tests are in progress to confirm these conclusions and to obtain significant quantitative relations.

(*d*) *Vibrational Properties.*—The dependence of Young's modulus and of the internal friction of wood on the frequency of vibration has been investigated in an attempt to find a relation between dynamic and static properties. Electromagnetic excitation and detection of vibrations were used at audio frequencies and the shape of the resonance curve measured. The differences in frequency between certain points on the resonance curve were found from the frequency of beats between a constant frequency oscillator and one tuned to a suitable known multiple of the frequency of vibration.

5. Timber Mechanics.

(Division of Forest Products.)

(*a*) *Studies of Properties and Testing Methods.*—Modulus of rupture results for both green and dry mountain ash specimens tested with the grain angle ranging from 0 to 90° to the plane of loading conformed to the Hankinson formula.

The presence of macroscopic compression failures on the face of a beam has been regarded as seriously reducing its strength when tensile stresses are subsequently applied. It has now been demonstrated for spruce, radiata pine, southern blue gum, yellow box, and red ironbark that prior loading to near the ultimate strength in bending (judged by the development of compression failures) does not significantly reduce the ultimate strength when the specimens are reversed. Even two such pre-loadings on opposite faces do not appreciably reduce the ultimate load, though the modulus of elasticity is reduced and the limit of proportionality raised.

Thermal coefficients of expansion have been studied on green specimens representative of five trees each of radiata pine, alpine ash, and mountain ash. Measurements have been made within the range 70 to 210° F. to obtain data for use in the investigation of the development of end-splits in veneer logs. Generally it can be said that coefficients are negative with increasing temperature for all directions of measurement and the longitudinal coefficient is very small.

The effect of heating on strength and modulus of elasticity in tension perpendicular to the grain has been studied on specimens representative of five trees each of radiata pine, Douglas fir, alpine ash, and mountain ash. The temperature ranged from 70 to 210° F. and duration of heating from four minutes to 72 hours. Generally both temperature and duration of preheating had a highly significant effect on strength and modulus of elasticity.

(*b*) *Species Testing.*—The determination of the mechanical properties of timber from standard tests on the more important Australian species continued throughout the year. Fifty-five species were represented including various eucalypts from Victoria, tallowwood from Queensland, and 23 species from New South Wales. In addition less comprehensive tests, generally on substandard specimens, were made on dry material from 110 miscellaneous Queensland species and green material from 42 Queensland species. Tests were conducted also on Fijian mahogany and the South American species *Mora excelsa.*

(*c*) *Silvicultural Tests.*—Strength-density correlations and the effect of age on strength and density are being studied on data from green and dry compression and bending specimens from ten logs of *P. pinaster,* three logs of *P. ponderosa,* two logs of *P. laricio,* and ten logs of *P. radiata.* Analysis is now proceeding. In addition a study was made of experimental errors in this investigation, and it was demonstrated that these were small. From data obtained in the investigation of the effects of growth factors on the strength properties of *P. radiata,* statistical analysis has shown that within any particular tree the strength-density relationship is unaffected by position around the tree or height in tree.

(*d*) *Timber Construction.*—Attention has been given to improving the efficiency and economy of the use of structural timber, with particular emphasis on glued construction. Structures designed and tested include a variety of solid, laminated floor beams of long span, trussed beams, and other building units. Interest has been stimulated in architects and engineers by the issue of notes on the technique of design and construction of laminated structures using Australian timbers. Notes have been issued also on the design of high-grade diving boards of laminated timber.

Long-duration loading tests have continued for periods up to nine years on specimens of three species loaded in tension, having split-ring and shear plate connectors. Statistical analyses have been made of much of the data and it is now proposed to report the investigation. Some specimens have been unloaded: among these all species and load ratios have been represented but in no case have the joints exhibited significant recovery of the slip developed while under load. A limited range of tests is being made on pressed-plate toothed connectors in radiata pine, and comparisons are being made with bolted and nailed joint. Nailed, pressed-plate connectors for use with scantling are also being studied.

Investigation of nailing characteristics of Australian species has continued throughout the year. Withdrawal resistance has been studied in the species karri, radiata pine, mountain ash, and messmate stringybark at various moisture conditions and changes therefrom. These tests are incomplete. The lateral strength of nailed joints is being studied in messmate stringybark. Initial testing is complete on joints using single nails with loading parallel to the grain, and investigations with the load applied perpendicular to the grain, and also on multiple-nailed joints have commenced.

Seventy-two additional model columns of 2 by 1½ inches cross-section were set up under constant long-duration loading this year, making a total of 290 columns erected to date. Of these, 213 have failed after periods ranging from one day to three years. Definite trends have not yet been established but the more slender columns appear to be able to survive for longer periods than the short columns. There is some indication that Douglas fir may be less severely affected by long-duration loading than the two eucalypts tested, only 48 Douglas fir columns out of 96 having failed, compared with 98 out of 123 mountain ash columns and 67 out of 81 yellow stringbark columns. The green columns which were allowed to dry while loaded tended to fail more quickly than those kept green, particularly for the eucalypts. Eighteen dry columns have been set up, most under loads equal to 70 per cent. of their estimated short-duration failing load, and five have failed after periods varying from four and a half to eight months.

Four columns of slenderness ration L/d = 10, which had carried 70 per cent. loads for at least two years and appeared relatively stable, were placed in a testing machine on several occasions and, without removal of the long-duration load, were subjected to numerous cycles of superimposed loading and unloading to simulate the application and removal of live loads. The columns behaved fairly elastically under the cycling loads, and for moderate overloads the subsequent lateral deflection under the long-duration load alone did not appear to increase at an appreciably faster rate than that before these tests.

Considerable progress has been made in testing to determine the influence of various defects on the strength of jarrah scantling, though sampling has so far been restricted to 4 by 2 inches cross-section. In all categories of defects, bending tests on the scantling and correlated tests on small clear specimens are nearing completion.

6. Timber Preservations.

(Division of Forest Products.)

(*a*) *General.*—There has been an increased burden of advisory work resulting from public awareness of the need for preservative treatment of outdoor constructional timbers. Several commercial plants are now projected or under construction and much time has been spent in assisting development of this industry by advising on economic aspects, plant design, and treatment schedules. Where necessary demonstrations or pilot treatments have been made in the Division's experimental plant to illustrate the practical application of modern treatment methods.

(*b*) *Field Tests.*—The numerous field and service tests of treated timbers installed by the Division during the past 25 years are now of great value both for practical demonstration of results and for selection of the most suitable treatments for commercial use. To maintain this important project, new tests are installed periodically, the present emphasis being on rail sleepers and fence posts. New sleeper tests include 433 treated jarrah, karri, and marri sleepers for service test in Western Australia, 575 treated radiata pine sleepers for installation in South Australia, and 100 treated New Zealand-grown radiata pine sleepers for comparative test with 420 Australian-grown pine sleepers treated during the year for tests in Victoria. Fence post tests include an additional 240 round posts, treated with "Greensalt" for test at the Toolangi Research Farm (Victoria), bringing the total at this site to 519 and the total in all States to almost 3,000.

(*c*) *Pressure Treatment of Refractory Timbers.*—Treatment at pressures up to 1,000 lb./square inch has continued to give good results with most eucalypt timbers refractory to treatment in the heartwood at lower pressures. Its practical application has now been demonstrated with some thousands of eucalypt sleepers of many different species. Overseas interest

in high pressure treatments has led to limited tests with European spruce and Douglas fir which have, however, proved unable to withstand the high pressures used with eucalypts. However, as radiata pine can be treated without damage at high pressures it is now obvious that resistance to crushing during treatment depends on the relative permeability of the wood as well as its strength.

(*d*) *Preservative Treatment of Fence Posts.*—Investigation has continued of methods suitable for the simple and economical treatment of round fence posts. The Division's mobile low-pressure plant has been widely demonstrated and used successfully for the treatment of seventeen different fence post species. A simple chain barking machine has been constructed to demonstrate the economic use of timber species which are not readily barked. A bulletin describing methods of treatment and simple equipment is now awaiting distribution to farmers.

(*e*) *Diffusion Treatments of Green Timber.*—Treatment of green building timbers by momentary immersion in a concentrated water-borne preservative, followed by block stacking to permit diffusion of chemicals into the wood, has shown considerable promise. Using a concentrated solution of sodium pentaborate, complete penetration of green eucalypt sapwood has been obtained after a block stacking period of four weeks. Commercial application to the treatment of sapwood susceptible to the *Lyctus* borer is being studied.

Promising results have also been obtained with klinki pine using a compound preservative containing 40 per cent. of fluoborates, arsenate, and chromate in aqueous solution. Commercial application of this treatment is being studied intensively in view of the urgent need for a simple treatment of this timber for housing in New Guinea.

(*f*) *Properties of Wood Preservatives.*—Leaching tests with sapwood blocks of mountain ash and radiata pine treated with various preservatives have been continued to determine the effect of pH of the leach water on rate of leaching from the wood. These tests are nearing completion and results are providing an essential key to the understanding of field performance.

(*g*) *Timber Mycology.*—In a survey of fungi causing blue stain in radiata pine in all States except Queensland, 84 per cent. of all isolations were identified as *Diplodia pinea* (Desm.) Kickx. Controlled tests made by the Timber Mechanics Section on sapwood specimens inoculated with this fungus and incubated for periods up to twelve weeks showed no loss in toughness, crushing strength, or modulus of rupture, although all specimens were severely strained. This result was obtained whether the material was tested in green or dry condition. Blue stain is objectional in cases for other reasons, but this result indicates that the low strength observed in certain case material must be due to other causes.

Laboratory studies of decay resistance have proceeded from the aspects of comparative testing of many different timbers, practical interpretation of results, and general improvements in technique. This latter work has included comparison of soil-jar methods, study of the decay-rate curve, and study of the effect of soil moisture content and jar aeration on the decay rate with different fungi.

(*h*) *Timber Borers.*—Tests of various preservatives to determine the lethal threshold to *Lyctus brunneus* are continuing. Zinc sulphate has proved ineffective at nominal salt retentions up to 1.8 per cent., but "Tanalith U", "Boliden BIS", and arsenic pentoxide have so far given complete protection at the lowest salt retentions tested, i.e., 0.05, 0.113, and 0.04 per cent. respectively. The threshold for boric acid is apparently again at approximately 0.14 per cent.

7. Timber Seasoning.

(Division of Forest Products.)

(*a*) *General.*—Industrial activity over the past year was reflected in increased demands for technical assistance to an extent much greater than previously experienced. Principal interest centred on the application of new seasoning techniques and emphasis was given to studies aiming at faster and more economic drying of timbers and veneers.

(*b*) *Collapse.*—Work was commenced to determine the pattern of collapse and appraise the importance of factors influencing recovery in size. Increased evidence was obtained of the inhibiting effects of tension wood on recovery at commercial plants. The influence of drying rate and drying conditions was examined. Absorbed inorganic salts did not significantly reduce collapse in susceptible material. Impregnation with sodium bicarbonate at pressures up to 1,000 lb./square inch., to form gas bubbles in the coarse capillary system, also proved of no value. It was shown that pretreatments removing lignin or hemicelluloses caused collapse which is largely irrecoverable and which approaches that of tension wood.

(*c*) *Drying Studies.*—Good progress was made in vapour drying jarrah, karri, mountain ash, messmate stringybark, and peppermint, in railway sleeper sizes. Using mineral turpentine, end-sealed half-length jarrah sleepers were vapour dried in ten hours to acceptable quality with average and surface (outer $\frac{3}{8}$ inch) moisture losses of 35 per cent. and 65 per cent. respectively: internal checking developed to a depth of about 1 inch. Subsequent five-hour impregnation treatments with a 50:50 creosote and oil mix at 800 lb./square inch. gave absorptions ranging from 6 to 10 lb./cubic foot. At least six months' air drying is necessary to ensure equivalent absorption.

Work was commenced on 1-inch thick backsawn karri which can be produced when larger sizes are being milled, but seasoning difficulties have limited its use. Chemical seasoning with a buffered sodium chloride treatment gave promising results, and the possibility of commercial application with a steam-quench technique is being examined. Kiln schedule work on yellow stringybark was commenced, and scout studies on southern mahogany, grey box, yertchuk, and maiden's gum were completed.

For platen-dried "ash" eucalypt veneers, it was established that gross shrinkage is a function of "dwell" time and a further factor depending on the time required for a thermally insulating steam layer to form on the platens. Superheated-steam drying studies were commenced and limited work on 1-inch thick radiata pine and karri was completed. The commercial application of drying schedules for veneer developed in the laboratory and incorporating an initial high drying temperature and large wet bulb depersion was confirmed with ramin and radiata pine veneers at a plywood mill. An examination of the drying characteristics of veneer of *Balanops australiana* was commenced.

(*d*) *Kiln Design and Equipment.*—A high-temperature, fast-drying kiln designed for tolerant species has reduced commercial drying times for 1-inch thick radiata pine from 80 to 48 hours. With minor modification it can be used as a superheated steam kiln.

The screened veneer drier was further developed. In commercial operation units are giving outputs approximating 10 to 15 square feet of 1/16-inch veneer per square foot of floor area per hour—a production equal to that obtained from multi-deck mechanical driers. Capital cost approximates one-quarter to one-third that of mechanical driers. With species not markedly collapse-susceptible or subject to cross grain, high-quality drying is obtained.

One hundred and fifty visits were made to wood-using plants to advise on kiln conversion, prevention of degrade, collapse and reconditioning, stacking and handling, kiln maintenance, shrinkage control, furnace kilns, instrumentation, the drying of Australian and overseas timbers, as well as to start up and test prototype equipment, to report on plant efficiency, and to advise on suitability of sites for proposed seasoning plants. Plant layouts were prepared for thirteen firms, and estimates of costs made. Design for kilns and redrying rooms for peeled and sliced veneers, sawn timbers, and turnery were prepared for 28 firms, and 510 drawings were issued. Charts were prepared to determine the influence of various factors on the cost of kiln heating. Performance tests were made on two large pre-driers. The grate arrangement of McCashney burners for valueless wood waste from sawmills, which is a dangerous fire hazard, was further improved. Drawings were issued to 81 firms.

(*e*) *Veneer and Gluing Studies.*—The peeling characteristics of *Celtis philippensis, Spondias dulcis, Ptercocymbium beccari,* and *Hernandia ovigera,* all New Guinea species, and the North Queensland species *Balanops australiana,* were examined. Tension wood, and splitting, decay, and spiral grain affected recovery in most cases. Studies were made on the peeling of karri, radiata pine, and Western yellow pine, and on the mechanics of peeling in relation to veneer quality and power consumption. Work was continued on veneer evaluation methods using a shadow technique for surface roughness and ink absorption for tightness.

Tannin-formaldehyde resins, and combinations of these with other synthetic resins, are being investigated in co-operation with the Division of Industrial Chemistry. A technique was developed for making termite baits from sawdust bonded with urea-formaldehyde. Scout studies were made on the effect of small gaps in three-ply centres on shear strength, the improved bond strength of some karri plywood made from preservative-treated veneers, the weathering of plywood, and the bonding of linoleum to hardboard and plywood.

(*f*) *Seasoning Corresponding Committee: British Commonwealth Forestry Conference.*—Active contact was maintained with the twelve member laboratories. Exchanges were made on the rating of seasoning degrade, case hardening, honeycombing, shrinkage measurement, end coating, pole drying, veneer drying, moistnre meters, and kiln schedules.

(*g*) *Miscellaneous.*—The sorption characteristics of fire hazard sticks were examined on behalf of a State Forest Service. The influence of stack height and strip size on the extent of board crushing caused during reconditioning of ash eucalypts was examined. It was found that at 15 per cent. moisture content the pressure on the stacking strip should not exceed 40 lb./square inch. An examination of the equipment and production methods of a firm manufacturing wood-wool cement products was made at the request of a State Department.

8. Timber Utilization.

(Division of Forest Products.)

(*a*) *Timber Uses.*—Information was supplied on the suitability of timbers for over 100 uses, and advice given on the properties and uses of 150 species. The Trade Promotion Branch, Department of Commerce and Agriculture, was assisted in preparing data for a handbook on Australian timbers.

(*b*) *Manufacturing Processes.*—The number of inquiries on sawmilling techniques and machinery indicated a growth of the Division's influence. Designs for sawmills were prepared for eight new sawmills and one woodworking factory, and modifications were proposed for seven operating sawmills. During visits to sawmills in Victoria, New South Wales, South Australia, and New Guinea, production practices were examined and suggestions made regarding possible improvements. Diagrams and illustrations of an automatic firewood docker published in the *Newsletter* aroused wide interest, and an engineer was subsequently assisted to start manufacturing this item. Information was given regarding the design or operational characteristics of log cranes, breaking-down circular saws, frame saws, log edgers, gangsaws, breast benches, bench gauges, ripsaws, resaws, dockers, planers, timber conveyors, sorting tables, edge sorters, timber loaders, barkers, chippers, hoggers, sawdust extractors, briquette-making machines, and sawdust fired burners for dispelling frosts. Advice was given on the manufacture of wood-wool, wood flour, furniture, mouldings, flush doors, and pegs; on distillation products, sawdust resin, and sawdust-cement mixtures; on the preparation of rattans and yacca gum; on the finishing of flooring and weatherboards; and on the bleaching of timber and the treatment for squeaking floors.

(*c*) *Waste Utilization.*—Investigations into aspects of the utilization of sawdust as a soil improver were continued. In field tests the use of fresh and partially hydrolysed sawdust showed reduced pasture plant establishment and nitrate content six months after incorporation. Nitrate content was lower in the treated sawdust than in the fresh sawdust plot at this stage, hut at twelve months this position was reversed. The reversal was not as early or as pronounced as expected from preliminary laboratory work, and it was concluded that the benefits from hydrolysing treatment were not commensurate with its cost. Investigations on these and other effects of saw dust on the soil are continuing.

Methods for accelerating decay of the non-lignin portion of finely divided wood waste were fnrther investigated with a view to developing a soil improver. A number of wood-rotting organisms were tested, some of which brought about rapid decomposition of waste from *Pinus radiata* and *E. regnans.* It was found that *Lenzites trabea* produced maximum decay (measured by loss in weight) when peptone equivalent to 0.32 per cent. nitrogen was added. With from 0.8 to 1.6 per cent. nitrogen, decomposition was less thau when no peptone was added. The part played by certain of the fungi imperfecti in breakdown of wood is being studied, and also the effect of partial decay by wood-rotting fungi on subsequent breakdown by soil micro-organisms.

Hardboards of attractive appearance and strength were produced experimentally from water-cooked sawdust.

(*d*) *Sawing.*—Studies were initiated to determine the power and energy consumed at the principal breast bench typically operated in hardwood sawmills. The results indicated that improved performance could be expected if feed speeds were adjusted with depths of cut, and this led to attainment of higher average rate of sawing and higher efficiency from the motor by maintaining load nearest its capacity.

Trials of an experimental bench incorporating a heavy flywheel were completed: these showed differences due to feed speed and saw speed, but not lesser differences due to number of saw-teeth, moisture content, and density. The main factors affecting the performance of both scratch- and gouge-type power saw chains with Australian woods have been established and the effects of modifications to gouge-type saw-teeth are being further investigated. A pendulum-type dynamometer is being made to study the action of single teeth. The forces operating during chip formation at slow speeds are also being investigated, single teeth in a standard static testing machine being used.

(*e*) *Standards.*—Collaboration with the Standards Association of Australia was continued and technical assistance given in drafting and reviewing proposed

standards. An officer of the Division acted as chairman for Sectional Committees on Wood Technology, Wood Utilization, and Portable Ladders. The Association published during the year Interim Standard 31-3-Interim Grading Rules for Radiata Pine Sawn and Milled Products. Committee work and voting were completed on a proposed standard for crossarms of eastern and south-eastern Australian hardwoods. Draft specifications for portable ladders were reviewed.

Liaison was maintained with the F.A.O. Permanent Committee on Standardization and Utilization in the Asia-Pacific region, membership maintained on sub-committees dealing with grading of hardwood logs and hardwood sawn timber, and comment submitted on draft grades.

XV. BUILDING.

1. General.

The building research work of the Organization is undertaken mainly by the Division of Building Research, Highett, Victoria, which collaborates closely with the Commonwealth Experimental Building Station of the Commonwealth Department of Works in New South Wales. Research is directed towards the study of the more effective use of available materials, the adaptation of traditional materials to new constructional methods, and the development of new materials and building techniques for the improvement of both the functional aspects of buildings and the efficiency of methods of construction. The work of the Division is reported in this Chapter.

Work on timber for constructional purposes is concentrated in the Division of Forest Products (*see* Chapter XIV.). Work on building foundations is undertaken by the Division of Soils (*see* Chapter II., Section 8), and work on cement and ceramics by the Division of Industrial Chemistry (*see* Chapter XVIII., Section 3).

Division of Building Research.—Although progress during the year has been generally satisfactory it has not been as good as had been hoped because of further financial restrictions and, even more important, the inability to recruit research staff. Consequently the important investigations into lightweight aggregates and gypsum plaster as a structural material have been greatly hampered, and work on bituminous materials, particularly their application to flat roof construction, has been severely restricted.

A pleasing feature has been the increased interest in the Division's work shown by the building industry. Thus, the Associated Fibrous Plaster Manufacturers of Australia have agreed to contribute a sum of £2,500 per annum for a minimum of three years so that the work may be resumed on the problems of the fibrous plaster industry that was stopped in 1951 because of lack of finance. The increasing use being made of the Division by the industry and the public is illustrated by the rise of 24 per cent. in the number of inquiries, of which 4,200 were received during the year.

The Division is co-operating with the New South Wales State Brickworks and the New South Wales Depatment of Public Works in developing a new type of downdraught brick kiln incorporating lightweight construction, insulation, and automatic stoking. Trials with the prototype resulted in reductions of nearly 50 per cent. in the fuel consumption and in the burning cycle of a conventional kiln, and a second kiln that will incorporate improvements found necessary as a result of the experience with the prototype is now being designed.

Numerous cases of expansion of brickwork in buildings, causing sliding on the damp courses, cracking, and other damage, have been drawn to the attention of the Division. Investigation of these has brought to light the important but previously overlooked fact that most burnt clay products expand irreversibly on exposure to moisture. It would appear desirable therefore that bricks and other structural clay units should be well soaked or weathered before use. The reasons for the expansion and means of overcoming it are being studied.

At the request of the Government of Western Australia the Division is assisting the heavy clay industry to improve the output and quality of its products and to establish a sand-lime brick industry in that State. Under the auspices of the Colombo plan, a young Ceylonese graduate is spending twelve months with the Division for training in research on clay products.

A senior member of the staff of the Royal Melbourne Technical College is working part-time in the Division on the development of three-dimensional acoustic models to gain research experience.

Courses of lectures have been given by officers of the Division to students of the University of Queensland, the University of Melbourne, and the Royal Melbourne Technical College. Addresses and lectures have been delivered to meetings of builders and clay products manufacturers, at extension courses of the University of Sydney, and at symposia on concrete technology in Melbourne. The Division contributed to a display on building research prepared by the Building Research Liaison Service for the 1954 Homes Exhibition in Melbourne.

2. Lightweight Aggregates.

(Division of Building Research.)

(a) Expanded or Bloated Clays and Shales.—The examination of raw materials for the manufacture of expanded clay or shale aggregate for lightweight concrete has been continued with tests on shales from the Adelaide and Melbourne areas. The work on the Adelaide shales is in a preliminary stage only, but trials with the Melbourne shales show these to be a very suitable raw material for an extensive lightweight aggregate industry.

Investigations into the use of these aggregates in concrete indicate that with those having low water absorption the water content of the mix and hence the workability of the concrete are easier to control than with those of higher water absorption. Aggregate made from shale has a water absorption lower than that of aggregate from clay.

(b) Perlite.—Much assistance has been given to manufacturers and potential manufacturers of the ultralightweight plaster and concrete aggregate perlite, and a wide range of perlite ores has been processed in the pilot plant.

The chemical and physical properties and the mineralogical compositions of the perlite ore and aggregates are now being investigated. Information from this work will permit the correlation of the composition and properties of the original ore with the behaviour of the expanded material, particularly as regards the secondary expansion which occurs in perlite plasters and concrete. The nature of the reactions involved is being examined. Attempts to inhibit the expansion by the addition of reagents to the mix have not proved satisfactory.

Tests to determine the amount of expansion likely to cause trouble and the magnitude of the forces set up when expanded plaster is restrained have shown that in some circumstances, at least, any stresses that develop are largely relieved by creep of the plaster.

The mechanical and physical properties of a wide range of mixes of perlite with portland cement and with gypsum plaster are being studied.

3. Concrete Investigations.

(Division of Building Research.)

(a) Theory of Rupture of Concrete.—In this investigation, which is to determine the stress/strain conditions governing the fracture of concrete, it has been

established that microcracks develop in unreinforced concrete specimens under load before the point at which they ultimately fail is reached. However, there does not appear to be any relationship between the cracking load and the ultimate load.

Strain measurements on concrete beams loaded up to 90 per cent. of their ultimate for nearly twelve months have shown that the creep of concrete is considerably higher in tension than in compression.

(*b*) *Shrinkage Studies.*—Carbon dioxide has been found to diminish greatly the shrinkage of concrete stored in it compared with that of concrete stored in air. Exploratory tests to examine this show that if concrete is brought, before drying, into contact with carbon dioxide its shrinkage is markedly decreased and its strength increased, whereas if it is allowed to dry out first there is an immediate increase in shrinkage followed by a stable condition and little further shrinkage.

The way in which the carbon dioxide combines with the concrete is now being studied by X-ray and thermal analyses of carbonated and uncarbonated mortars, and work is in progress on the effect of different humidity conditions on the interaction of carbon dioxide and concrete.

(*c*) *Cellular Concrete.*—The work on foamed concrete has given way to investigations on lightweight calcium silicate, a cellular constructional material of high strength produced by autoclaving a mix of hydrated lime and silica flour. Studies of the effects of gap and continuous gradings of the silica flour on the compressive stength of the calcium silicate have shown that the strength/weight ratio is increased by about 20 per cent. if gap-graded instead of continuous-graded silica flour is used. The effects of various curing conditions on the compressive strength of light-weight calcium silicate have been examined.

4. Gypsum Plaster and Plaster Products.

(Division of Building Research.)

(*a*) *Fundamental Research.*—Fundamental research to obtain a detailed knowledge of the processes involved in the dehydration of gypsum and the setting of gypsum plaster is being undertaken because of the wide variations in the properties of these materials. Different calcining processes must be used to obtain comparable plasters from different gypsums and it is believed that this is necessitated by variation in the gypsums arising from the ways in which they were formed. In this regard, thermobalance examinations have shown that the dehydration properties of set plaster are very different from those of the gypsum from which the plaster was made.

When plaster is used in hot, dry areas the possibility of it undergoing dehydration has to be considered; however, studies of its behaviour at 104° F. showed that, contrary to published data, there was no appreciable loss of moisture until the relative humidity was below 1 per cent.

(*b*) *Moisture Absorption of Plaster.*—Absorption of atmospheric moisture by plaster, both before and after setting, is being measured because of the importance of such knowledge in determining safe conditions of storage and because of the relationship it may have to some of the problems of the decoration of fibrous plaster. It has been found that plaster, even if dehydrated almost to the anhydrite stage, rapidly absorbs atmospheric moisture until, at 65 per cent., relative humidity, it contains about 8 per cent. of water, the formula then approximating to $CaSO_4.2/3H_2O$. Set plaster absorbs moisture very rapidly at humidities above 98 per cent.

(*c*) *Structural Gypsum.*—Structural gypsum is being increasingly used for houses and other buildings but design with it is chiefly on an empirical basis.

The work on reinforced gypsum has been extended to provide detailed information on the physical and mechanical properties of cast gypsum plaster in general, similar to that on cement concrete.

Particular attention is being given to the creep of gypsum plaster. This is important in determining the behaviour of plaster when subjected to the long-term loads that would be met in practice.

Some tests on the strength of cast gypsum at ages of up to twelve months show that, for specimens stored under constant atmospheric conditions, there is no significant gain in the compressive strength after one month. Soaking of the 12-month-old specimens in water reduced the compressive strength by half.

(*d*) *Fibrous Plaster.*—(i) *Decoration.*—Although the cause of "sulphide staining" is now well established and methods of control are available, the problem of the satisfactory decoration of fibrous plaster is far from solved. The reasons for damp staining at or near to joints, the flaking of certain water paints, and the loss of gloss and excessive condensation on styrene-butadiene latex paints still require elucidation.

So far, it has not been possible to do more than make observations of the behaviour of test ceilings painted under known conditions with a variety of paints and sealers. The damp stains on the two test ceilings referred to in the 1953-54 Annual Report occurred during humid summer weather but did not re-appear during the winter despite frequent periods of high humidity. However, sulphide stains have appeared, chiefly on the areas that were formerly damp stained. The flaking of water paints was frequently accompanied by efflorescence and was most marked on plaster sheets containing salt. The newer styrene-butadiene paint when used on fibrous plaster become covered with moisture at certain times. The reason for this is not yet known but it is not due to condensation through abnormally high atmospheric humidity.

(ii) *Expansive Plaster.*—Damage to fibrous plaster ceiling sheets by buckling has been found to be the result of expansion of the sheets after erection. This was thought to be due possibly to delayed hydration of part of the plaster, a circumstance which could arise through the presence of incompletely mixed plaster. Trials with completely and incompletely stirred plaster mixes showed that the rate of hydration of the latter was markedly less than that of the former.

5. Lime and Lime Products.

(Division of Building Research.)

(*a*) *Correction of Unsoundness in Magnesian Limes.*—Further studies of the oxychlorides formed in the salt treatment for overcoming the unsoundness of magnesian limes have shown that the reactions involved are complex. The stable oxychlorides 3- and 5MgO. $MgCl_2.xH_2O$ appear to arise from other more ill-defined oxychlorides.

(*b*) *Standard Test for "Soundness" of Lime.*—In attempts to find a simple standard method for determining the soundness of limes, best results have been obtained with a test in which sand-lime mortars in Le Chatelier moulds are autoclaved at a pressure of 240 lb. per square inch.

(*c*) *Sand-lime Bricks.*—Technical assistance on the suitability of raw materials and on matters concerned with plant and equipment has been given to several companies proposing to manufacture sand-lime bricks.

No water penetration or other trouble has been observed with the experimental sand-lime brick walls.

(*d*) *Survey of Australian Lime Industry.*—A detailed examination of the coastal limestone deposits in the Perth area of Western Australia has been made, and the industrial possibilities of the limestone deposits in certain areas of New South Wales have been assessed.

6. Clays and Clay Products.

(Division of Building Research.)

(*a*) *Clay Research.*—(i) *Regional Studies of Australian Heavy Clays.*—The survey of the structural clay products industry has been completed by further visits to all States during the year. Reports on the clay resources of Australia and on the structural clay products industries of the various States and Australian regions are being prepared.

The study of the mineral composition and particle size distribution of brick and tile clays from the country areas of Victoria is now almost complete.

(ii) *Constitution and Properties of Clay Minerals.* The elucidation of the structural changes that take place in vermiculite when it is heated in accordance with differential thermal analysis methods has been sought. It is evident that when vermiculites are hydrated or dehydrated the changes in water content and in the spacings between layers are subject to a hysteresis effect which clearly indicates that the natural state of any sample is very dependent on its previous history.

The effect of piperidine saturation in the differential thermal analysis of clay minerals has been examined and it appears that this method may be used to provide further evidence of the presence of illite and montmorillonite minerals in clay mixtures.

(iii) *Deterioration of Roofing Tiles and Expansion of Clay Products.*—For some time the Division has been investigating the deterioration of roofing tiles on roofs along the sea fronts of Victoria, and it has now been found that there may be a relationship between this problem and the expansion of brickwork, several cases of which have been reported.

An important fundamental property of most clay products is that they expand irreversibly when they become wet, and in studies of this behaviour with kiln-fresh bricks and roofing tiles it was found that the amount of expansion depended on the composition of the material used and the rate of expansion on the temperature of firing, and was greater in products fired at low temperatures. Bricks and tiles that expand most, and parts of tiles that remain moist for long periods through being protected by overlapping, undergo the greatest deterioration on exposure.

(*b*) *Clay Technology.*—(i) *Pilot Plant*—Clays from areas in Victoria, New South Wales, Queensland, Northern Territory, and Western Australia have been examined in the pilot plant for their suitability for various types of ceramic product.

(ii) *Kiln Design.*—To study the effectiveness of automatic firing and insulation in ceramic kilns an experimental downdraught kiln has been designed by officers of this Division in co-operation with officers of the New South Wales State Brickworks. The kiln, which has 9-in. internal walls of refractory vermiculite concrete, 9-in. external walls of solid brickwork, and a 1-ft. suspended roof of vermiculite concrete, has a capacity of 13,000 bricks and is fired with black coal by two mechanical underfed stokers. Preliminary trials showed that fuel consumption and the burning cycle were only about half of those of conventional downdraught kilns.

7. Caulking Compounds.

(Division of Building Research.)

(*a*) *Cold-flux Mastics.*—Cold-flux mastics for the sealing of joints consist of an oil and a solids component (powdered bitumen, asbestos fibre, and mineral filler) for mixing on the site as required. Examination in detail of the properties of various possible ingredients indicate that hard, powdered, air-blown bitumen with short-fibre asbestos and talc or slate powder as filler forms a suitable solids component for use with an oil such as a napthenic-type mineral oil. Mastics made with mica or limestone fillers swelled on immersion in water, possibly because of the presence of soluble salts.

(*b*) *Bituminous Emulsion Joint Sealers.*—Trials with clay-stabilized bituminous emulsions as joint sealers for underground concrete pipes showed shrinkages as high as 40 per cent. Asbestos fibre incorporated as a filler reduced the shrinkage slightly. Large proportions appear to be necessary to reduce it to a reasonable level.

8. Bituminous Roofing.

(Division of Building Research.)

(*a*) *Properties of Roofing Bitumens.*—The main requirement of a bonding bitumen for a built-up roof is that its viscosity should change as little as possible with change in temperature so that it is neither too brittle at low temperatures nor too soft at high temperatures. These requirements are best met by highly blown bitumens, but it has been found that they are likely to harden considerably if they are over-heated during roof laying, whereas less highly blown bitumens have been found to be little affected even by gross overheating. Despite this disadvantage the highly blown bitumens are to be preferred for roof bonding work.

To provide information on the suitability of various bitumens for roofing purposes the slumping tendencies of membranes bonded with the bitumens and exposed at an angle of 45° facing north is being assessed. So far, the test has shown that light-coloured mineral surfacing such as river gravel is of advantage in reducing slump by lowering the temperature of the membrane (even though the weight of the surfacing tends to cause slump), and that the penetration index, which is a measure of the change of viscosity with temperature, is preferable to the penetration, which is measured at a given temperature, as a criterion in the choosing of roofing bitumens.

(*b*) *Aluminium Foil as a Reflective Finish.*—Measurements of the tensile strengths of aluminium foil and several saturated felts have shown that the aluminium had the highest elongation at failure. This, however, is not of great benefit as most of the elongation is not recoverable; in fact aluminium foil as a roof membrane has been found to "grow", causing it to project beyond the roof line, or else wrinkle and buckle. Allowance for this behaviour must be made when aluminium foil is used as a membrane. Laying in lengths of not more than 20 feet is a considerable help.

Several instances of the failure of aluminium foil by rupturing have been investigated. The causes of these appear to be the laying of the foil on a considerable slope, painting a dark colour (which destroys the heat-reflecting properties of the aluminium), laying lengths of foil greater than 20 feet, providing excessively wide laps, and using too hard a bitumen.

(*c*) *Asbestos-cement Tiles as a Surface Finish.*—Earlier work showed that sheets of asbestos cement $\frac{1}{4}$-in. thick were unsatisfactory as a reflecting surface finish for bituminous roofs because they buckled during drying. Laboratory trials on 1-ft. square tiles cut from $\frac{3}{8}$-in. asbestos cement were more successful, and indicated that they were likely to give no trouble in service through buckling and would be suitable for roof decks subject to light traffic. A field trial with tiles of different sizes is in progress.

(*d*) *Field Investigations.*—The construction and subsequent observation of the performance of experimental bituminous roof membranes has for many years been an integral part of the work and has assisted in evaluating the relative merits of various techniques and materials used in bituminous membrane construction. The field rating obtained in the examination of the membranes are being assembled on "Hollerith" punched cards for ready extraction of the information they contain.

9. Concrete Floors.

(Division of Building Research.)

From investigations on the suitability of concrete floors for domestic dwellings it appears that such floors are comparable in performance with the conventional timber floors, and in fact have some advantages. Estimates of the costs of the two systems, concrete floor and timber floor, for two house plans and based on current unit rates indicate a considerable saving with the concrete floor.

The need for a waterproof membrane under a concrete floor to prevent penetration of moisture has been examined further by a survey of concrete-floored houses in Melbourne and Sydney. This shows that failure by penetration of moisture is the exception rather than the rule, even when little or no moisture barrier has been provided.

From calculations it appears that the temperature in winter of a house with a concrete floor on the ground compares favorably with that of one with a suspended timber floor, and an experimental check of this is being made.

10. Thermal Investigations.

(Division of Building Research.)

(*a*) *House Insulation and Heating.*—The amount of insulation that can be economically justified in a house depends on the period during which comfort heating is required. No evidence has been available to assess this period under Australian conditions, but an estimate has been prepared based on records kept by 80 families for the period April to September, 1954. From these data the approximate hours of heating during the winter months in the various Australian capital cities have been calculated.

(*b*) *Floor Heating.*—Heating by sources located in the floor of a room is often considered to be the ideal method for, by its use, a low floor-to-ceiling temperature gradient and a higher proportion of "radiant" heating can be achieved. Several aspects of this subject are now being investigated. The distribution of radiant energy transfer from the body to its surroundings has been studied by measuring the "radiation" from an illuminated model falling on surfaces representing the walls, floor, and ceiling of a room. In general, it was found that the proportion of radiation transfer to the floor was considerably less than the area of the floor relative to the walls and ceiling, and from this it can be shown that claims that a warm floor will heat by radiation without heating the air are unjustified.

11. Architectural Acoustics.

(Division of Building Research.)

Investigations on architectural acoustics aim at the rationalization of the acoustical design of concert halls and auditoria in general, with particular reference to the use of three-dimensional acoustic models. It has been shown that the acoustic impedance of the model walls should match that of the full-size space but, since perfect matching is obviously physically impossible, the effect of small changes in impedance has been studied and correlated with the effect of variations implicit in the tolerances of the model.

The commonly used method of assessing the acoustical quality of halls is not entirely satisfactory and several simpler methods have been proposed by various workers. One of these, which entails the measurement of variation of the response of a hall to a sound of single frequency which is slowly increased in frequency, has been examined by this Division. The results suggest that, because the single frequency is not representative of the complex sounds met in practice, it would be dangerous to draw conclusions by this method about the acoustics of a space.

Successful trials with the speaker column method of sound reinforcement for improving listening conditions were made in several churches and a very large hall in Melbourne. The length of the large hall made it necessary to supplement the speaker columns with an electronic delay unit that reduced echoes at the back of the hall.

Measurements of the effects of discontinuities on acoustic filter design have been continued and the work has been extended to cover the case where there are reflections from the terminating duct. The characteristic factors of some typical discontinuities have been measured also. So far, there is no adequate theory for the prediction of these factors from a knowledge of the geometry of the discontinuity, and experimental determination is the only possible way.

12. Other Investigations.

(Division of Building Research.)

(*a*) *Experimental Stress Analysis.*—Loading tests on two prestressed concrete beams have given information on stress losses in the prestressing wires, the relationship between calculated cracking loads and those obtained under test, and the mechanism of ultimate failure.

The creep of three loaded unreinforced concrete beams is being measured over a long period by means of electrical resistance strain gauges which are proving sufficiently stable to provide consistent results. Magnetostrictive stress gauges for embedding in concrete test specimens have been developed, but modifications are needed to increase their sensitivity to permit the measurement of shrinkage stresses in concrete.

(*b*) *Non-destructive Testing.*—The application of gamma-ray radiation from cobalt 60 to the measurement of density has been examined for a wide variety of building materials and a correlation between the transmission of the radiation and the density over the range 25 to 150 lb./cubic foot has been found. This method would make possible the measurement of the density of *in situ* materials.

(*c*) *Sprayed Vinyl Coatings ("Liquid Envelope").*—Tests have been continued on the ability of thick vinyl resin waterproofing coatings to withstand alternating strains. One sample has withstood over 7,300 cycles of stretching and recovery of 0.06 inch per hour over a gap of 0.15 inch.

From examination of a case of embrittlement of a vinyl resin film applied over a bituminous surfacing on a flat roof it would appear advisable to avoid contact between vinyl resins and bituminous materials.

XVI. WOOL TEXTILES.

1. General.

An extensive programme of research has been undertaken with the aim of improving the use of wool as a textile fibre. This work is complementary to research in sheep husbandry, described in Chapters V., VI., and VII., which is aimed at increasing the quality and production of wool. The major aims of wool textile research are: (i) to increase the knowledge and understanding of the complex structure of the wool fibre and its physical and chemical properties; (ii) to use this knowledge to improve wool as a textile fibre, to improve technology in wool processing, and to utilize by-products more fully; (iii) to improve machinery used in wool textile manufacture. In these ways it is hoped to preserve wool's unique position amongst the world's textile fibres.

The Organization's work in this field has been distributed among three Wool Textile Research Laboratories, as follows:—

(i) The Melbourne Laboratory at Parkville is responsible for research on the structure and chemical reactivity of wool and on the carbonizing process.

(ii) The Geelong Laboratory at Belmont is responsible for technological investigations.

(iii) The Sydney Laboratory at Ryde carries out research on the physics of wool and the physical and engineering aspects of wool processing.

The Division of Industrial Chemistry has continued a study of the constituents of wool wax and possible ways of utilizing them or their derivatives (*see* Section 4 of this Chapter). It is also studying the structure of proteins in relation to wool (*see* Section 10 of this Chapter). The Division of Entomology is continuing to study the digestive processes of wool-eating insects and larvae (*see* Chapter IX., Section 2).

Wool Textile Research Laboratories.—Additional accommodation has become available during the year at all three centres. In Geelong the completion of a new building has made it possible to install additional full-scale textile machinery for experimental and developmental work on woollen and worsted processing. Some of the machines were not previously available in Australia, and industrial representatives have appreciated the opportunity to become familiar with these latest developments. In Sydney and Melbourne the building extensions have relieved congestion in the laboratories, workshops, and stores.

In recognition of the excellent opportunities available overseas for research staff to learn of recent advances in wool textile research and in associated fields of science, several officers of the Wool Textile Research Laboratories have visited other countries for post-graduate study and experience. Some have held C.S.I.R.O. Studentships or Traineeships in specific aspects of wool research. A senior engineer was awarded a Fellowship financed from funds provided by the Associated Woollen and Worsted Textile Manufacturers of Australia to enable him to work in the Department of Textile Industries at Leeds University on the theory of roving structure and on drafting. In addition, two senior officers visited research institutions in America and Europe to acquaint themselves with overseas developments and to facilitate arrangements for the forthcoming International Wool Textile Research Conference. This is to be held for three weeks at the Wool Textile Research Laboratories in Sydney, Geelong, and Melbourne between 22nd August and 9th September, 1955.

In July, 1954, publication was commenced of "Wool Textile News" which aims to bring before the wool textile industry in a readily understandable form the latest research results from both the C.S.I.R.O. laboratories and research establishments overseas.

Co-operation in research has been continued between the Wool Textile Research Laboratories and universities and technical institutes. In Sydney, for example, one officer has been able to carry out research on the supercontraction of wool and on the uptake of surface-active agents in the School of Applied Chemistry of the New South Wales University of Technology. Another has undertaken X-ray diffraction studies in the School of Applied Physics in the same university on the structural changes in wool fibres during stretching. Similarly wool textile firms in various States have been interested to test newly developed processes, and in Sydney facilities have been placed at the disposal of our officers to assist with engineering studies of wool textile processing. Such co-operation, both on the part of our higher institutes of learning and the wool textile industry, represents an important contribution to research progress, which is gratefully acknowledged.

Joint researches have been arranged between officers working in different Wool Textile Research Laboratories where it was likely that progress in dealing with a particular problem would be assisted by bringing together different types of experience and technique. Thus the mechanism of shrinkage conferred on wool by a resin process developed at the Geelong Laboratory has been studied at Sydney.

2. Raw Wool.

(Wool Textile Research Laboratories.)

(*a*) *Branding Fluids.*—New L.B.E. Branding Fluid was widely used during 1954, over 72,000 gallons being marketed by various firms in Australia; the fluid was also made and used in other wool-growing countries. In the meantime, further research has resulted in the development of a fluid which can be safely applied to wet sheep and completely resists removal by rain falling during or after application of the brand. The trade name "SI-RO-MARK" has been registered by the Organization for this new product. The registered trade name may be used under licence by manufacturers who comply with certain conditions in manufacturing the brand and whose product satisfies certain tests. With these precautions it should be possible to ensure that graziers are able to obtain a uniform material made strictly in accordance with the recommendations of the Organization. Already twenty Australian firms have been licensed to use the trade name and inquiries have been received from other wool-growing countries where the fluid is likely to be widely used.

(*b*) *Fellmongering.*—Improvements in fellmongering practice are still being made through the gradual adoption of recommendations based on the results of the Organization's research completed during the past few years. Temperature regulating equipment is being widely used to control the rate of bacterial growth during the sweating of sheepskins, and the loss of depilatory action due to the use of excessively high concentrations of sodium sulphide in depilatory paints is now recognized and avoided.

Heat shrinkage of the skin pieces followed by vigorous aeration to promote the release of wool by bacterial digestion of the skin tissues have been widely adopted. An interesting development, which resulted from an attempt to squeeze water out of shrunken skin pieces during an examination of this process at a New Zealand fellmongery, led to the design of a new machine for recovering the wool. This machine pulls the wool out of the shrunken skin so that the necessity for subsequent skin digestion by the enzyme or aerated warm-water processes is avoided.

(*c*) *Solvent Degreasing.*—Additional combing trials have been made on large batches of wool of different qualities treated by the jet solvent degreasing unit. In all instances, greater yields of top were obtained and there is little doubt that wool processed in this way has distinct industrial advantages. Worsted processors are showing great interest in the plant and preliminary arrangements are being made for the installation of a commercial unit in one large Australian worsted combing mill. Certain overseas firms are also showing considerable interest in the method. Further advantages of the solvent degreasing process are that the tops produced are whiter in colour than those produced from the same wool by normal scouring methods; almost complete recovery of lanolin is effected by solvent distillation, which is an essential step in the process; much less space is occupied by the equipment than by normal scouring plant; less steam is used; and the effluent disposal problem is eliminated. Moreover, it may be possible to recover the potash as an additional by-product of the solvent process, and appropriate exploratory experiments are now in hand.

(*d*) *Carbonizing.*—Satisfactory methods have been developed firstly, for measuring the damage to wool by sulphuric acid—the method is sufficiently sensitive

to detect the effect of acid even when used at concentrations below those employed in the carbonizing process —and secondly, for measuring the ease of crushing burrs after acid treatment and baking. These procedures are enabling a vigorous search to be made for agents which promote the action of sulphuric acid on burrs or reduce its action on the wool. Unexpectedly low resistance to carbonizing has been observed with burrs of the species *Medicago minima* grown in one particular locality.

3. Fleece By-products.

(Wool Textile Research Laboratories.)

(*a*) *Wool Wax.*—The flotation method of recovery has been developed further and is now in use in four Australian wool-scouring plants. Factors such as age of liquor, concentration of soap solution used in scouring, and rate of feed to flotation cells have all been found to affect recovery figures. It is therefore essential that such variables be carefully controlled in order to obtain optimum recovery by the method.

(*b*) *Potash.*—In view of the demand for potash as a fertilizer, a survey is being made of the potash content of greasy wool from different districts. Preliminary results indicate a potassium content of the order of 1.5 per cent. of fleece weight, and the possibility of recovering this from scour liquors will shortly be examined.

4. Derivatives from Wool Wax and Suint.

(Division of Industrial Chemistry.)

(*a*) *Wool Wax.*—A major portion of the programme of research into the chemical nature of wool wax has now been completed with the isolation and identification of all the members of the series of aliphatic alcohols entering into the ester portion of wool wax. The aliphatic alcohols, forming 22.5 per cent. of the total alcohols, are composed of 2-3 per cent. normal alcohols, 9-9.5 per cent. each of *iso-* and ante *iso* alcohols and 1.5 per cent. diols. The normal alcohols have a longer average chain length than their corresponding acids.

The fractionating molecular still, which is to be used in an attempt to separate the individual esters as such, is completed and is undergoing tests.

Solvent fractionation of wool wax has produced a range of fractions of widely differing physical properties. Their composition and chemical properties are being determined with a view to their utilization, and samples have been sent to potential industrial users.

Research designed to seek possible outlets for the lanosterol of wool wax as a raw material for fine chemicals of biological or therapeutic interest is in progress. A compound structurally similar to the natural sex hormone, progesterone, has been prepared as a starting material for other hormone analogues. The results of biological tests are awaited. A convenient method has also been found for the conversion of lanosterol to a hydroxy-acid with ring contraction to produce the nucleus found in the biologically active steroids.

A study has begun of the spontaneous oxidation of wool wax by atmospheric oxygen, which is doubtless responsible for its deterioration. To assist in the understanding of the process, the chemistry of the autoxidation of lanosterol itself and of its synthetic long-chain esters is being examined.

In collaboration with the Division of Entomology, a project is being undertaken to determine the features of a steroid molecule necessary to promote the growth of certain insects, as it is known that cholesterol is a growth factor in such cases, and the possibility of synthesizing toxic antimetabolites is envisaged.

(*b*) *Suint.*—An investigation of the organic constituents of suint has been commenced. Suint is the mixture of water-soluble substances present in the raw fleece. It appears from previous work to consist largely of the potassium soaps of fatty acids and other water-soluble acids, together with amino acids and other nitrogenous substances. However, no fatty acid has been identified with certainty. The work is initially concerned with the fatty and water-soluble acid constituents.

5. Wool Textile Processes.

(Wool Textile Research Laboratories.)

(*a*) *Yarn Manufacture.*—The worsted drawing process is being investigated since it is one of the fundamental steps in making worsted yarn. A member of the Geelong staff stationed at the Wool Industries Research Association, Leeds, has used a radioactive tracer technique to study the movements of fibres during drafting. The work indicates that irregularity in worsted slivers is due to break-down in general continuity conditions rather than to fibre accelerations as previously assumed. The radioactive technique has now been used also to assess the number of contacts between fibres in slivers at densities encountered in practice. Results show that fibre contacts can be quite high, increasing with sliver density up to 300 per cm.

The frictional forces in oiled yarns, when examined under conditions comparable with those encountered in practice, have been shown to be not critically dependent on the quantity and viscosity of the oil applied.

In another investigation into the configuration and strain of single fibres during worsted yarn manufacture, using a radioactive tracer technique and undertaken at the Sydney Laboratory, fibres have been impregnated with a radioactive phosphorus compound and then singly replaced in the main lot of wool at an early stage in processing. As the fibre passes with the wool through subsequent machines it is located by means of a Geiger counter unit. A photographic film is then pressed against the wool and the radiations from the single treated fibre make an imprint of the fibre on the film. This is called an autoradiograph. The autoradiographs are analysed for changes in shape, particularly in respect of fibre crimp and fibre extension. The studies are proving most fruitful and have already given information concerning changes in the amount of crimp and in the amount of strain at various stages up to the spinning processes.

(*b*) *Weaving.*—For plain weave cloths from 2/30's and 2/40's yarns it has been shown that, in most cases, almost all the observed reduction in yarn strength during weaving is due to abrasion of the yarn by the moving parts of the loom and not to the cyclic variations in yarn tension.

(*c*) *Bleaching and Dyeing.*—Research is in progress to develop methods of improving fastness to washing of wool dyes. A detailed study has been made of factors affecting the ease of removal of acid dyes from wool in order to determine the dyeing conditions giving optimum wet fastness properties. In addition, the possibility of improving the wet fastness of acid dyes by chemical modification of the wool and by various after-treatments is being investigated. Work is also in progress to determine whether the wool itself plays a part chemically in the fading of acid dyes.

6. Modification of Wool.

(Wool Textile Research Laboratories.)

(*a*) *Shrink-proofing.*—The "SI-RO-FIX" process, which involves the treatment of wool with an alcoholic solution of caustic alkali and polyamide

resin has been further developed. Pilot-scale equipment has been installed to permit impregnation of the fabric with a very small quantity of solntion using an hydraulic press; this obviates the necessity for standing baths of the impregnating liquor. The same technique has been applied to allow the treatment of wool with alcoholic alkali alone, and represents an advance over previous methods of shrinkproofing with this reagent.

A method has also been developed for shrinkproofing wool with a solution of unsubstituted polyamide (i.e. nylon) in alcoholic sulphuric acid, which would be cheaper than the "SI-RO-FIX" process.

Other cheaper methods of shrinkproofing using protein materials are also being investigated. Successful shrinkproofing has been obtained, for example, by impregnating the fabric with casein or gelatin and hardening the protein deposit with formaldehyde *in situ*. These deposits, however, are not as effective as the polyamides in withstanding hot aqueous acid solntions, such as those used in dyeing.

All resins or other materials which prevent felting by bonding the fibres together rely on adhesion to the wool fibre for their effect, and it has been found that, for optimum results, the wool requires some form of pretreatment to increase this adhesion. The exact nature of the change produced by a desirable pretreatment is now being investigated.

(*b*) *Physics of Polymer Deposition.*—A considerable number of experimental treatments for resin deposition for shrinkproofing cloth have been examined by physical methods involving stereomicroscopy, staining, sectioning, shadowing, and micromanipulation. Distinct differences in the formation of the resin on and between fibres for different resins has been shown. The correlation with shrinkproofing processes is being sought in collaboration with the chemists engaged on the project.

(*c*) *Mothproofing.*—Two lines of work have been pursued in this field. Firstly, it has been found that certain anionic surface-active agents when applied to wool during dyeing confer resistance to moth attack. A wide range of such products has been examined and many of these have been found effective. However, these agents are not sufficiently fast to washing and further work will be necessary to overcome this disadvantage.

Secondly, encouraging results have been obtained using the new insecticide dieldrin and related compounds. Preliminary tests indicate that these compounds after application to fabrics are fast to both washing and dry-cleaning. Some industrial trials are now in progress in which the insecticide is being applied under a variety of mill conditions. The method may provide a convenient and cheap means of mothproofing wool.

7. Physics of Wool and Fibre Assemblies.

(Wool Textile Research Laboratories.)

(*a*) *Mechanical Properties of Single Wool Fibres.*—The permanent crimp of wool is one of its outstanding properties since it makes an important contribution to the properties of heat insulation and resilience which are characteristic of fabrics made from wool. An investigation of the load-extension curve of wool fibres over the decrimping range has shown that the elastic properties in bending differ from those concerned when extending the fibre. The decrimping curve has been correlated mathematically with the physical properties and shape of the fibre.

The mechanical properties of single fibres during 5 to 20 per cent. extension in water have also been stndied.

(*b*) *Regain of Wool.*—Research into the interaction of wool and water has been increased because of its great importance in commercial transactions, in manufacture, in textile end-use, and in understanding the basic structure of wool. The way in which mechanical properties of wool are profoundly affected by the amount of water in wool is also of great interest.

The regain of several samples of wool has been measured accurately for a range of temperatures and relative humidities, and measurements have been made of the amount and rate of swelling when a dry fibre is immersed in water. This has given valuable information on the way in which water enters and diffnses into each wool fibre.

Methods have also been developed for measuring the rate at which a single wool fibre takes up water from an air stream at various values of relative hnmidity.

(*c*) *Thermal Conductivity of Fabrics.*—A simple and accurate method for the measurement of thermal conductivity of cloth has been developed. Measnrements on cloths covering a range of ends and picks per inch show that the density of a cloth is more important than its thickness.

8. Histology of Wool Fibres.

(Wool Textile Research Laboratories.)

An understanding of the mechanical, physical, and chemical properties of wool largely depends on the extent of knowledge of its structure and of its reactivity with other substances. Studies of wool fibre structure are therefore being vigorously pursued with the aid of all available scientific tools and techniques to yield information on structural detail both at the microscopic and submicroscopic levels. Optical microscopy and histochemical methods are being used, for example, to yield further information on the bilateral strncture of Merino wool. This property is certainly closely related to crimp since the S cells, which are located in one half of the cross-section of fine, highly crimped wool fibres, are located in the centre of coarse fibres leaving a ring of H cells distributed around the periphery. Two segments cannot therefore be distinguished in very coarse wool fibres.

Further application of the gold shadowing techniqne in conjunction with visual microscopy has enabled detailed studies to be made of the well-known Allwörden reaction for fibre damage nsing both chlorine and bromine water. The membranes of the bubbles formed at the surfaces of undamaged wool fibres on treating with chlorine water are composed of structureless epicuticle, whereas ribs and furrows can be seen in the underlying exocuticle attached to the epicuticle in the membrances released with bromine water. The shadowing technique has been used to reveal the strnctnre of resistant membranes and other material isolated from oxidized wool, for example, of the nuclear remnants obtained from the cortical cells and the closely related fibrils. It has also allowed the imprint of the scale edges on the adjacent underlying cortical cells to be demonstrated, and likewise damage to the fibre surfaces by treatment with chlorine, bromine, sulphuric acid, and trypsin. The main virtue of the method lies in the great amount of detail which can be detected at comparatively low magnification and thus without the necessity for restricting the field under examination at any one time to a very small area as in electron microscopy. The relationship of fine structural details to coarser features of the fibres are thus revealed, and the location of fine structures in the fibre can be established with certainty.

9. Wool Protein Chemistry.

(Wool Textile Research Laboratories.)

Structural details of wool at submicroscopic levels of magnification are being obtained by examination of the wool proteins *in situ* using physical methods, such as infra-red and X-ray spectroscopy. However, details of the structure of individual protein constituents of the fibre are more readily obtained by extracting the wool proteins and applying to them a wide range of methods which have been developed for the study of soluble proteins. Recent progress in this direction is summarized in the following section.

(*a*) *Preparation and Properties of Wool Protein Solutions.*—The major protein of wool, termed component 2 or kerateine 2, which has been obtained electrophoretically pure by fractional extraction with alkaline thioglycollate, has now been extensively studied at the Melbourne laboratory. Additional peaks appearing in the descending pattern during electrophoresis in thioglycollate solution are attributed to the strong tendency of this protein to combine with itself, but this can be eliminated by increasing the salt content or decreasing the protein content of the solution. The tendency of this wool protein to aggregate may play some part in the growth of wool in the skin follicle. The molecular weight of kerateine 2 determined by the surface balance method was shown to be about 32,000, but the molecules dissociated into smaller units of molecular weight 8,000 at low protein and salt concentration. Amino acid analysis showed that kerateine 2 contained more aspartic and glutamic acid residues and amide nitrogen but less cystine and proline than the parent wool.

Chemical derivatives of the mixed proteins extracted from wool with alkaline thioglycollate were prepared at the Rockefeller Institute in the United States of America some twenty years ago. Now that the major wool protein can be prepared electrophoretically pure, it has been possible to extend this work by making the corresponding derivatives of the pure protein and thereby producing modified wool proteins which are stable in the absence of thioglycollate and therefore very suitable for characterization by various chemical methods.

Intact wool has also been repeatedly reduced with thioglycollate under conditions which avoid damage to peptide bonds to split all the disulphide bonds. Their reformation has been prevented by interaction of the sulphydryl groups with iodoacetamide, and the solubility properties of this modified wool have been investigated.

Another project has been concerned with the study of soluble derivatives obtained by oxidizing the disulphide bonds of wool with peracetic acid and dispersing the product in ammonia. Electrophoresis and sedimentation studies in the ultracentrifuge agree in showing that the protein solution so obtained contains molecules of various dimensions. The presence of these different molecular species is attributed to aggregation and changes in shape of the wool proteins. Reliable measurements of the sedimentation properties of the wool proteins have been made possible by improving the design of the available ultracentrifuge to enable heat generated by friction to be removed as it is produced.

(*b*) *Amino Acid Composition of Wool.*—Analyses are now being made of a series of wool samples taken from Merino sheep used in the C.S.I.R.O. strain trial experiment (*see* Chapter VII., Section 14). These are revealing the extent to which the composition of wool varies between different areas on the body of individual sheep, between different sheep of the same strain, and between different Merino strains.

(*c*) *Peptide Chemistry.*—Various methods have been compared for linking together the building stones of wool, that is, the amino acids, to form peptides, and a series of cystine peptides and related compounds has been prepared for studies of the effect of peptide structure on the chemical reactivity of the cystine disulphide bond. Already the reactivity of this bond has been shown to vary with the nature of the adjacent groups.

(*d*) *Infra-red Spectroscopy.*—Data have been assembled on the infra-red absorption characteristics of particular groups in proteins and an absorption band has been identified corresponding to amide side chains. The properties of the band show the manner in which these groups are oriented in relation to the wool fibre axis.

10. Protein Structure.

(Division of Industrial Chemistry.)

The Division of Industrial Chemistry has continued its investigation on the structure of proteins, particularly the fibrous proteins, such as wool, hair, and muscle. Fundamental to this work is the synthesis of a crystallizable peptide sufficiently long to show the proposed helical structure of the polypeptide chains in proteins. In the preliminary investigations glycine peptides up to octaglycine have been prepared, but low solubilities prevent further extension of chains of this single residue. The synthesis of a series of peptides in which every fourth residue is L-leucine is being attempted. New facts in the chemistry of phthaloylated and *o*-carboxybenzoylated amino acids and peptides have been recorded. Also, a new and unusual reaction, of considerable significance in the field of peptide synthesis, has been discovered. The acid chlorides of the *p*-toluene sulphonyl derivatives of aliphatic α-amino acids have been shown to be degraded readily by cold aqueous alkali to *p*-toluene sulphonamide, a carboxyl compound, carbon monoxide, and the choride ion. A mechanism has been proposed and the study of this reaction extended.

X-ray studies of the amino acids, the ultimate units from which proteins are composed, have been continued. The structure of aspartic acid hydrochloride has been refined to the limit imposed by the experimental data. This analysis has established the importance of several factors in achieving high accuracy in single-crystal structure analyses in general. X-ray molecular structure studies reported elsewhere (*see* Chapter XVIII., Section 6 (*b*)) have led to new analytical methods for structure which are of significance to the protein structure investigations. Computing machines being developed and built in the Division for structure analysis computation are a basic necessity for the protein and peptide structure studies.

Electron miscrocopical studies of ultra-thin sections of wool fibres and wool follicles have provided a fairly complete picture, at the fine histological level, of the development of the fully keratinized fibre from the cells of the wool root. The recently discovered bilateral structure of wool fibres has been shown to arise from an earlier and more complete fusion of the keratin fibrils on one side of the fibre cortex. Studies with the electron microscope on the structure and function of muscle have been continued.

11. Biological Degradation of Textiles.

(Wool Textile Research Laboratories.)

(*a*) *Wool Damage by Bacteria.*—The development of a suitable method of sterilizing wool without damaging its proteins is being attempted for use in studies of the susceptibility of wool to attack by various bacteria.

(*b*) *Fungal Degradation of Cellulose.*—Of the enzymes produced by the cellulose-destroying fungus *Stachybotrys atra*, the β-glucosidase which attacks the bond linking glucose to another unit other than a sugar has been well characterized. Methods of preparing and partly purifying the enzyme cellulase, which initiates attack on cellulose, have also been worked out.

A new process has been developed for mouldproofing canvas which depends on converting about 1 in 200 of the glucose residues in cellulose into a more reactive group but without splitting the main cellulose chains. The converted groups are then allowed to react with a protective reagent. In laboratory trials canvas protected in this way has withstood rotting in soil burial tests. The method is now being further studied and attempts are being made to cheapen the process.

12. General Protein Investigations.

(Wool Textile Research Laboratories.)

(*a*) *Collagen.*—The action of two proteolytic enzymes, trypsin and collagenase, from the bacterium *Clostridium welchii* on various collagen preparations has been compared. Close similarity has been observed between them except that collagenase attacks collagen soluble in acetic acid more rapidly than does trypsin. However, too small a proportion of the skin proteins is digested by these enzymes for them to be used for the release of soluble fragments from skin for study by other chemical methods.

(*b*) *Pure Proteins.*—To assist in developing methods suitable for the study of wool proteins, investigations have been continued with pure proteins. The cystine-containing protein, insulin, for example, has been studied with the aid of the surface balance. Its molecular weight has been shown to be about 6,000 in acid solution and to remain at this value in less acid solutions only if the concentration remains very low.

Another pure protein, lysozyme, has been used in studies of amino acid sequences. By splitting the protein into small peptides with acid and isolating and identifying these, a number of sequences in the parent molecule have been identified.

XVII. PLANT FIBRES.

1. General.

Only two plant fibres, cotton and flax, are produced commercially in Australia or Australian Territories, although the possibilities of developing other fibres such as kenaf, ramie, manila hemp, and coir are being investigated. The cotton industry, begun in Queensland about 30 years ago, contributes a small but increasing proportion of the country's requirements of this fibre. The Australian flax industry, greatly expanded under government control during the war, is now well established and able to supply the whole of the local demand. The Plant Fibre Section was established originally to assist with the problems of the flax industry and was then known as the Flax Research Laboratory. This Section was subsequently expanded to include work on a number of other plant fibres as well.

Plant Fibre Section.—Until recently the activities of the Section embraced a wide field of research on agricultural, processing, manufacturing, and utilization problems of plant fibre products. During the past twelve months, however, the work of the Section has been transferred to problems of fodder conservation (*see* Chapter III., Section 24). The Section has nevertheless continued to cooperate with the Flax Commission, the Victorian Department of Agriculture, and the Department of Territories, in research on the processing and spinning of fibres.

2. Agricultural Investigations.

(Plant Fibre Section.)

Fibre yield and spinning tests have shown that several of the new rust-resistant flax varieties developed by the Victorian Department of Agriculture equal or excel, under local conditions, the best of the imported varieties, all of which are susceptible to the strains of rust present in this country. The effect of the use of modern weedicides on the development of fibre in the growing flax plant is being studied. Field trials of kenaf in Papua and New Guinea have produced fibre which has been spun by the Plant Fibre Section into yarns comparable with the best yarns of imported jute.

3. Processing and Utilization.

(Plant Fibre Section.)

(*a*) *Water Retting.*—Investigations of the technique of water retting flax with aeration of the liquor during the process have now been concluded. This method greatly reduces the retting period without impairing the spinning quality of the fibre.

Some small-scale investigations have been made of the water retting of coconut fibre, considerable quantities of which are now available in New Guinea.

(*b*) *Scutching.*—Improvements on the performance of the standard type of scutching machine in use in flax mills in Australia have been shown to result from various modifications suggested by the Section.

(*c*) *Preparing and Spinning.*—The laboratory spinning plant has been fully occupied with the evaluation of fibre from various field and processing investigations. Further information has been gained on the use of Australian timbers for pressing rollers and preliminary studies of the kier boiling of flax yarns were concluded.

(*d*) *Utilization.*—The feasibility of using flax fibre for blending with wool has been demonstrated, but further work is necessary before the costs can be calculated.

4. Fundamental Fibre Investigations.

(Plant Fibre Section.)

(*a*) *Microbiology of Retting Bacteria.*—This work is now being concluded. It has made possible a much more intelligent understanding of the subject.

(*b*) *Chemistry of Cellulosic Fibres.*—The non-cellulosic constituents of flax fibre are being studied in their relation to spinning quality.

(*c*) *Physical Properties of Fibres and Yarns.*—A study has been made of the characteristics of Australian and overseas products for the manufacture of linen shoe thread. It has been concluded that Australian fibre is at least equal to that used overseas for the purpose.

5. Fodder Conservation.

(Plant Fibre Section.)

This work is reported in Chapter III., Section 24.

XVIII. INDUSTRIAL CHEMISTRY.

1. General.

The Division of Industrial Chemistry represents the major concentration of chemical research within the Organization, although much chemical work is undertaken in other Divisions and Sections.

This Division was formed: (*a*) to promote greater technical efficiency in established industries; (*b*) to stimulate the establishment of new industries; (*c*) to encourage the use of raw materials of Australian origin; (*d*) to seek substitutes for imported materials; and (*e*) to find uses for by-products not utilized.

In addition to its basic chemical work, the main research activities within the Division deal with mineral utilization, cement, ceramics and refractories, organic chemicals, wool, brown coal, and water conservation.

The Division's study of the constituents of wool wax and possible ways of utilizing them or their derivatives is described in Chapter XVI., Section 4. The Division is also studying the structure of proteins in relation to wool (*see* Chapter XVI., Section 10). The Division's work on the utilization of brown coal is described in Chapter XX., Section 6.

The work of the Organization's Tracer Elements Investigations Unit in the procurement and distribution of radioactive isotopes and the preparation of isotopically labelled components is described in Section 9 of this chapter.

Division of Industrial Chemistry.—During the ten years since the conclusion of World War II. many members of the research staff of the Division have been fortunate in being able to further their scientific training by periods spent in university departments and other research institutions in England and the United States of America. In the past there has been little opportunity to repay in like manner the hospitality that our officers have received during these visits overseas. It is thus a source of gratification that recently some members of research institutions in other countries have considered the Fishermen's Bend Laboratory a favorable environment for development of their particular fields of research and have sought to spend substantial periods at the Laboratory as guest workers (*see* Chapter I., Section 14).

The Division has, over a period of nearly ten years, collaborated with the Division of Plant Industry, the Chemistry and Physiology Departments of the Universities, and with State and Commonwealth Government Departments in undertaking a survey of the alkaloids present in the native flora of Australia and New Guinea and in examining their pharmacological properties. The collection of plant specimens required for this survey, a task of considerable magnitude, has been performed on a part-time basis mainly by officers of the Division of Plant Industry and the Queensland Forestry Department. Because of other responsibilities these officers have not always been able to meet all the demands made for collections, and an appointment is being made to this Division for full-time work in this field. The officer appointed will continue to receive assistance from the Division of Plant Industry and his work will be under the immediate direction of a member of that Division with wide experience in plant collection. The comprehensive pharmacological testing of plant extracts produced in the survey is a most important adjunct to its success. Later in this report reference is made to new arrangements whereby industrial pharmaceutical firms will collaborate in this section of the programme.

The Chief of the Division spent six months during the year visiting research institutes overseas with the special object of investigating arrangements between these institutes and industry for collaborative research. This aspect of the Division's activities promises to grow in importance. An investigation of methods for purification of sugar solutions has been carried on in co-operation with the Colonial Sugar Refining Co. and substantial progress has been made with two other major projects undertaken as sponsored investigations, one on behalf of Mount Morgan Ltd. and the Mount Lyell Mining and Railway Co. Ltd. jointly, and the other for the Australian Atomic Energy Commission. Experience has shown that projects of this kind, when appropriate to the Division's general research programme, can be of great value both to the sponsors and to the Division.

Officers of the Division have continued to engage actively in the work of international scientific organizations. Dr. A. L. G. Rees has continued as a member of the Commission of Physico-chemical Data and Standards of the International Union of Pure and Applied Chemistry; the Chemical Physics Section is contributing to the work of this Commission through the study of the ionization potentials of atoms and molecules. Dr. A. McL. Mathieson and Mr. A. J. Gaskin attended the Third Congress of the International Union of Crystallography in Paris in 1954 and the former acted as chairman at one of the sessions of the Congress.

2. Minerals Utilization.

(Division of Industrial Chemistry.)

Projects related to various phases of extractive metallurgy continued to form an important part of the programme. In general the objective has been to devise new or improved methods for the separation of one or more metals from the various extraneous substances with which they are commonly associated in Australian ores. In some instances the emphasis has been more on the isolation of some enriched or convenient compound of the metal than on the preparation of the metal itself. Projects in the above category include hydrometallurgical studies on copper, uranium, zirconium, hafnium, thorium, certain of the lanthanons, and germanium.

Apart from their metallic components some natural minerals and synthetic inorganic compounds have useful properties that devolve entirely on their physical characteristics. Investigations based on the study of mineral derivatives in this class constitute a second group of projects. This includes various lamellar compounds of graphite and analogous substances, synthetic semi-conductors, dry lubricants, phototropic compounds, and lanthanon derivatives.

Investigations in X-ray crystallography, inorganic chemical analysis, pressure digestion reactions, fluorine production, and valency characteristics have also been undertaken.

(*a*) *Hydrometallurgy of Copper.*—Work has been continued on methods of extracting copper from the calcines obtained by roasting of chalcopyrite concentrates from Mount Lyell and Mount Morgan in a fluid bed. The effects of the most important variables, viz., time, temperature, and acid strength on the amounts of iron and copper leached by agitation with sulphuric acid, have been assessed, and attempts made to correlate solubility with roasting conditions. The kinetics and mechanism of the oxidation of ferrous iron by manganese dioxide and by air have also been studied, since oxidation followed by precipitation offers a promising method of removing iron, arsenic, antimony, and molybdenum—elements which reduce the efficiency of the electrolytic deposition of copper. The current efficiency of deposition has been shown to be closely dependent on the iron content of the electrolyte and on those variables which influence diffusion.

(*b*) *Uranium Extraction.*—The study of acid pressure leaching has been continued with a number of different Australian uranium ores. A reactor for continuous, as opposed to batch, operation has been designed and employed to evaluate the possibilities of the process for full-scale use. Further work was undertaken on the settling and filtration problems associated with the processing of Rum Jungle ores. Alkaline leaching procedures were investigated as a means of reducing the cost of processing such local uranium ores as contain large amounts of acid-consuming components. A detailed study has been completed of the leaching techniques required for treatment of ore from the Mary Kathleen lease in Queensland, and significant contributions made towards an understanding of the very unusual mineralization occurring at this locality. Much time was devoted to service work for the Australian Atomic Energy Commission and 32 technical notes were issued as a result of these investigations. Apart from testing and analysis of uranium-bearing samples from eleven different localities, the Commission has been advised regarding the amenability of different ores to the procedure at present in use at Rum Jungle, Northern Territory.

(*c*) *Zirconium-Hafnium Separation.*—Fundamental investigations into new methods for removing hafnium from zirconium have continued to yield interesting results, and a pound-scale pilot plant for separating

these two elements has been designed, assembled, and successfully put into operation. Other studies in the field of zirconium chemistry have included a detailed examination of some of the addition reactions of zirconium iodide. The compounds formed in this way possess quite unusual properties and some of the reactions of these complexes may help to elucidate the covalent metatheses which are so characteristic of the chemistry of zirconium. Close liaison with other research centres interested in zirconium has been maintained and a series of investigations in collaboration with the School of Metallurgy, Melbourne University, arranged. The current joint programme of work concerns the electrolytic deposition of zirconium from fused salt solutions of its lower valency halides.

(*d*) *Thorium and Lanthanon Chemistry.*—Work on an alkaline process for the decomposition of monazite was completed. Although alkaline reagents are expensive in Australia compared with the sulphuric acid used in earlier work, the alkaline process enables simplifications to be made in the subsequent recovery steps. A relatively simple procedure for recovery, in high yield, of all major components of the mineral has been devised. The thorium concentrate so produced is amenable to purification by methods developed in the Division; lanthanon and uranium concentrates are treated by established methods. A method has also been devised for the recovery of a substantial portion of the uranium contained in the liquors which remain after the acid processing of monazite. Studies on the relative distribution of the various lanthanons in a number of Australian minerals have been continued. Western Australian fergusonite was found to be a relatively rich source of ytterbium, thulium, erbium, and dysprosium. Thulium has been proposed as a convenient portable source of X-rays, and preliminary separations by ion-exchange methods showed that extraction of this component from the above-mentioned source presents no peculiar difficulties. Western Australian gadolinite, and davidite from South Australia, were also investigated as possible sources of thulium. In connexion with the iodide metallurgy of thorium a study of the synthesis of thorium carbide was completed, and iodination studies of this material were commenced. The object of this work is the elucidation of the mechanism of the production of thorium and related metals by the method involving thermal decomposition of the iodides.

(*e*) *Germanium Survey.*—The chemical examination of flue dusts from metallurgical works and coal-burning plants has been continued with the object of assessing Australian sources of germanium and obtaining data on its distribution in smelting and coal combustion operations. Particular attention has been given to a determination of the distribution of the germanium content of a coal between the products of its carbonization. Examination of a wide range of products has shown that small amounts of germanium are widely distributed through Australian flue dusts with the highest relative concentrations occurring in flue dusts from producer-gas plants. Other types of flue dusts have not yielded enrichments of germanium sufficient for extraction by existing methods. A potentially greater quantity of germanium is available from these latter sources, but the necessary treatment of the extremely low-grade materials calls for entirely new techniques for extraction, a phase of the problem which was commenced in the latter part of the year.

(*f*) *Lamellar Compounds.*—Studies on the formation of many new lamellar compounds of graphite have been continued. It has been established that the intercalation process is a general phenomenon and is not, as previously supposed, peculiar to graphite. It was shown that crystalline boron nitride and various other crystalline substances also possessing a layer lattice structure are capable of forming stable lamellar compounds by intercalation of foreign substances in their interplanar spaces. Extension of the theory relating to this work has indicated that the phenomenon need not be confined to crystalline materials with the layer lattice structure. Magnetic susceptibility measurements made on some of the new graphite compounds have yielded results of theoretical importance, the most significant of these being the observed paramagnetism of the tripositive gold ion. Attention has been directed towards developing useful applications for some of the graphite compounds. For example, the incorporation of graphite compounds in the carbon brushes of electric motors was examined to determine whether such additions would enhance the performance of the brushes when these are subjected to extreme conditions. Some progress was also made with an investigation concerned with the possibility of employing graphite compound formation as a means of reducing undesirable deposition of carbon in internal combustion engines.

(*g*) *Phototropic Compounds.*—Previous work had shown that certain impurities, incorporated in the rutile modification of titanium dioxide by heating, cause light-sensitive colour changes. Chromium, iron, nickel, copper, and some of the rare earths are particularly active in this respect. Of these impurities iron yields the strongest coloration on exposure to light, and 0.005 per cent. is sufficient to cause noticeable darkening. Provided the impurities are present in small amounts the titanium oxide remains white until irradiated. The darkening produced is completely reversible in the dark but reversion may take a period ranging from hours to several months in the case of chromium activation. The presence of incorporated water has been shown to be essential for the effect to appear. In view of the practical implications of this phenomenon, where titanium oxide pigments and analogous materials are involved, work was continued on both the theoretical and applied aspects. From theory it was concluded that certain other oxides should act as "hosts" to impurities and inhibit phototropism also. This was confirmed for the white oxides of tin, aluminium, columbium, and probably tantalum, which give reversible colour changes on irradiation when contaminated with one or other of the impurities listed above.

(*h*) *Transition Group Sulphides.*—Work on the synthesis, constitution, and physical characteristics of the sulphides of titanium, zirconium, and hafnium has been continued. The higher sulphides of titanium and zirconium have been tested as dry lubricants. In the temperature range 20–350° C. their performance is comparable with that of molybdenum disulphide. The comparative ease with which they may be synthesized and thereafter ground to fine powder may render them useful solid lubricants. The electrical resistivities of a wide range of compositions in the systems Ti-S and Zr-S were determined. A study of the adsorption of oxygen on zirconium disulphide was completed and work on the synthesis of hafnium sulphide has indicated that hafnium probably forms only a monosulphide.

(i) *Chemical Crystallography.*—The examination of chemically imperfect oxide systems has been continued. Vanadium pentoxide, when crystallized in the presence of small amounts of sodium, forms two crystalline compounds of varying composition. One of these was examined by X-ray crystallographic methods and proved to be a molecular tunnel compound. Like the tungsten bronzes, to which it is related, it is an electronic conductor. The anomalous magnetic properties of compounds containing trivalent manganese were examined in a collaborative study with Professor R. S. Nyholm. This work necessitated a redetermination of the crystal structure of manganite, MnO(OH).

3. Cement and Ceramics.

(Division of Industrial Chemistry.)

Current projects fall into two main groups, one of which is concerned with the production and properties of cements and concretes, the other with ceramic and refractory materials.

The cement group has continued to deal with a wide variety of projects, most of which are designed either to improve concrete quality or to prevent deterioration. A key factor affecting both the initial strength and the subsequent weathering properties of concretes is crack development. This very complex subject is currently receiving most attention. Advisory work of the group has ranged from the investigation of aggregates for major concrete structures, to the prevention of corrosion of foundations and the clearance of vegetable growth from hydro-electric supply races. The Cement and Concrete Association of Australia has continued to provide valuable industrial collaboration and financial assistance.

The ceramics group has been concerned mainly with the production and utilization of refractories, the occurrence and properties of clays and related raw materials, and with certain fundamental features of shaping techniques used in the ceramic industry. Refractories are receiving increased attention because of the wide general utility of these materials in a number of vital industries, and also because the great quantity of refractory bricks and shapes consumed annually demands as much production from Australian raw materials as possible. The group has continued to give assistance in connexion with problems submitted by various ceramic manufacturers and other firms such as those using clays for paper production and oil bleaching.

(*a*) *Cement Hydration.*—Investigation of the products of the action of water on primary cement compounds is proceeding in order to provide basic information for research on the improvement of setting and hardening characteristics. X-ray diffraction and isobaric dehydration methods have thrown some light on the hydration mechanism of pure analogues of the compounds occurring in clinker from commercial kilns. Attempts are being made to synthesize larger quantities of pure clinker compounds.

A related topic is concerned with hydration and sulphation of the glass phase of cement clinker. The glass has proved to be more reactive than the crystalline components; it hydrates to give products similar to those of tricalcium aluminate, and is capable of subsequent reaction with sulphates to cause deterioration. This finding is in conflict with the practice of using low-heat cements in attempts to form sulphate-resistant concretes, since such cements contain reactive aluminous glass.

(*b*) *Cement-aggregate Bond.*—Little is known about the mechanism of adhesion of set cement paste to aggregate. This subject is a necessary complement to work on setting, hardening, and cracking of concretes. Preliminary measurements are being made of the strength of the bond between set cement and chemically and physically different aggregate surfaces. It may be possible to assess, from these data, the relative importance of chemical reaction and physical interlocking as factors in producing the bond.

(*c*) *Crack Development and Behaviour.*—All investigations on the strength and durability of cement and concrete are to some extent concerned with cracks, commonly of microscopic size, set up in the brittle material by dimensional changes due to a number of independent causes. Reproducible modes of cracking have been established by means of apparatus producing controlled deformation. The rapid break-down of cement paste in tension has been clearly distinguished from a slower type of progressive failure characteristic of mortar and concrete. A new effect noted is the action of solutions of divalent salts in propagating existing cracks. This type of crack expansion and propagation can be prevented by use of certain surface-active agents.

(*d*) *Air Entrainment.*—In a study of air entrainment using surface-active agents it has been shown that the basic mechanism, previously deduced for cement pastes, also applies to mortars and concretes. Emphasis has now shifted to the study of the effects of certain agents on workability and segregation. Beneficial features may be produced, without entrainment of air, by these additions during the mixing of concretes.

(*e*) *Additives for Reduction of Permeability.*—A number of surface coatings may give useful results on concretes exposed to aggressive waters, acids, sulphates, or severe weathering conditions. The limiting factors for most coatings are lack of flexibility and poor adhesion, so that most attention in the current work is being devoted to the newer plastics and synthetic rubbers. Some of these have been found to adhere strongly to cement, at the same time having sufficient flexibility to follow the dimensional changes of the base material. A useful feature of some additives in this group is the ease with which they may be mixed integrally with the concrete. Attempts are also being made to produce concrete surfaces resistant to plant growth by integral addition of toxic substances. Field trials have been set up to assess the efficiency of these surfaces under adverse conditions in supply races of power stations, where moss growth restricts water flow and causes severe deterioration of the concrete.

(*f*) *Weathering Cycles and Concrete Deterioration.*—Exposure to temperature and humidity cycles produces a number of stress patterns in concrete specimens, leading to microcracking and progressive disintegration. Crack prevention by air entrainment is being assessed in relation to the effects of surface-active agents referred to above. Crack protection methods are under consideration as a means of avoiding freeze-thaw break-down, a subject of increasing importance in large areas of the Snowy Mountains scheme.

(*g*) *Pozzolanas.*—A more complete picture of local sources of natural cements has been obtained. Certain rock types from Rabaul and northern New Guinea have economic possibilities, particularly in view of the improved resistance to severe weathering that can follow their use, and their natural price advantage over imported cements.

Methods for the activation of pozzolanas have been devised and patented. Treatment involves a small increase in cost, but can lead to great improvements in setting rates. Work on shrinkage reduction has revealed that in cements generally, overall shrinkage is greater when a curing period precedes exposure.

(*h*) *Refractories for Cement Kilns.*—Application of the results of a study of operating stresses in a cement kiln has resulted in longer life for the refractory lining despite an increased rate of production. Further data have been obtained by measuring stress inequalities in an operating rotary kiln. Study of the phase-equilibrium system relevant to reactions at the hot face of the lining has shown that satisfactory clinker coatings can only be built up by using a specific heating schedule. A miniature rotary kiln has been made to enable close control to be exercised during experiments on lining design.

(*i*) *Silica Refractories.*—Further investigation has established the fact that silica refractories are embrittled by the action of certain gases at high temperatures. This appears to be an inherent property of the material, but no evidence has been found that would suggest a mechanism for the change.

Improvements in the method of fabricating bricks from Australian "silcrete" have been made, and a trial panel of these refractories has been set up in an industrial steel furnace.

Preliminary experiments have been made to find out the effects of brown coal ash on silica bricks and other types of refractory bricks at high temperatures.

(*j*) *Special Ceramics and Cermets.*—Attention has been focused mainly on the fabrication of superrefractory articles from magnesia, the preparation of alumina-chromium cermets, and hot-pressing as a forming technique for production of hard and refractory materials. An improved method of slip-casting oxide shapes has been developed, using special additives to provide green strength and permit successful mould release.

(*k*) *Clay Mineralogy.*—Studies of clays received from Western Australia and Queensland are now complete, and the results are being prepared for publication. An examination of an attapulgite from Queensland showed that it did not match imported material in bleaching and gelling qualities. The evidence suggests that this is connected with the relatively large particle size and high crystal perfection of the local mineral.

Further fundamental work on the bonding of water molecules by vermiculite has provided a clearer picture of the complex detail involved. In co-operation with the Division of Building Research, a chapter on the differential thermal analysis of vermiculite has been prepared for a monograph to be published by the Mineralogical Society of London.

(*l*) *Whiteware and Related Investigations.*—Further studies have been made of the development of orientation effects in clays during processing in the ceramic industry. Quantitative assessments of orientation were developed from measurements on small rutile prisms present in certain clays. Attempts have been made to find what method of measuring drying and firing shrinkage best represents the subsequent industrial behaviour of clays and bodies. Studies on recovery of clays from deformation have shown the importance of "trigger" stresses developed during drying, a feature which can cause production losses throughout industry. Preliminary work on the study of the deformation of plastic clay by a penetrometer method has followed the development of a suitable instrument.

A co-operative project with a research group in the Department of Colloid Science at Cambridge University has resulted in basic advances correlating the "tube-rolling" phenomenon shown by plastic clay with a general theory which explains the behaviour of all visco-elastic materials under shearing stresses. New observations have shown the importance of stick-slip effects as a basic cause of dilatancy in solid-liquid mixtures. A novel design of the Weissenberg rheogoniometer has been produced, in which the range of the apparatus has been extended from liquids to plastic solids by the use of flexible boundary surfaces. It is hoped that consistent basic explanations of the behaviour of plastic ceramic bodies may be derived from this fundamental approach.

(*m*) *Adelaide Ceramics Laboratory.*—Advisory and developmental work for local industries concerned with the manufacture of pottery, building materials, and refractories, has continued with the support of the School of Mines and Industries and the Department of Mines. Deposits of raw materials have been examined, the properties of the resulting samples determined, and the best methods of fabrication demonstrated. Particular attention is being devoted to the use of extrusion processes in heavy-clay industries.

4. Foundry Sands.

(Division of Industrial Chemistry.)

The laboratory, situated in the Metallurgy Department of the Melbourne Technical College, is equipped for specialized testing of moulding sands; examination of sand samples submitted by industrial firms, and advisory work on sand conditioning and control procedures constitute major activities. A catalogue is maintained of moulding sand deposits situated near the principal industrial centres of Australia; much additional information has been obtained from tests on samples collected during the year.

The Section provides an advisory service for the foundry industry. Advice has been given in response to many inquiries on general metallurgical problems. This service has involved numerous minor laboratory investigations.

Australian bentonitic clays have been examined in relation to their application as substitutes for imported bentonite in the preparation of synthetic moulding sands.

5. Physical Chemistry.

(Division of Industrial Chemistry.)

The conservation and use of water, and the properties of surfaces and of fluids are the subjects with which the research programme is principally concerned. Fundamental studies includes investigations of carbon and charcoals, chemical reactions proceeding at high pressures, the thermodynamic properties important in distillation, and the action of enzymes which use gases, like nitrogen, directly. Applied investigations include the selective flotation of a tin mineral, the control of evaporation of water under natural conditions, the use of filters in rubber, and the engineering development of ion-exchange processes.

(*a*) *Properties of Liquids.*—The investigation of thermodynamic properties of liquids and solutions, important in the design of industrial distillation equipment, has been continued. Particular attention has been paid to solutions containing alcohols and polar liquids.

The compositions of the vapours in equilibrium with mixtures containing nitromethane, benzene, and carbon tetrachloride have been measured. Heats of mixing at temperatures up to 45° C. have been measured for the systems benzene-carbon tetrachloride, benzene-ethylene dichloride, acetone-chloroform, ethanol - carbon tetrachloride, ethanol - *iso* - octane, ethanol-benzene, ethanol-toluene, ethanol-methyl *cyclo*-hexane, and acetonitrile-carbon tetrachloride. Experimental and theoretical methods have been combined in an attempt to determine the intermolecular forces which govern the properties of mixtures such as these.

The compressibility of some organic liquids and their mixtures with water have been measured at pressures as high as 2,000 atmospheres. It was found, paradoxically, that the addition of a small amount of a highly compressible liquid (e.g., an alcohol) decreases the already low compressibility of water.

(*b*) *The Chemical Effect of High Pressure.*—Although high pressures are being used industrially for the production of a few chemicals, the lack of knowledge of the effect of pressure, particularly for reactions in the liquid state, has proved to be a deterrent to the use of pressure as an important weapon for production of chemicals. The pressure range in the laboratory has been extended over the past twelve months from 15,000 to 30,000 atmospheres. A 200-ton hydraulic press has been installed which will permit extension of the pressure range to 50,000 atmospheres. It will also be of value in experimenting at lower pressures with larger quantities of liquids than could hitherto be used.

The study of simple organic reactions at the higher pressures has confirmed the theory that reactions which produce ions from neutral molecules are assisted by pressure. Similarly, pressure markedly affects the equilibrium between simple and complex ions.

(*c*) *Mass Transfer.*—The industrial process of solvent extraction requires transfer of a wanted substance from a liquid or solid to the extracting liquid. The effect of speed of flow of liquid has been shown to conform to a theoretical picture based on a description of the flow of liquid around a sphere at Reynolds' numbers between 500 and 6,000.

(*d*) *Flotation of Tin Ores.*—As a result of continued work on the ore from Maranboy, Northern Territory, a flotation process has been developed which, for batch tests in the laboratory, gives promise of recoveries of tin substantially greater than are possible by conventional gravity methods. The rougher flotation stage is based on earlier work of the group using the reagent sodium hexadecyl sulphate as collector, but this work has been extended to study in detail the role of both ferric and ferrous iron in the solution, and to devise means for their control. In this way the consumption of both collector and sulphuric acid has been reduced. Sodium silicofluoride has been shown to be an effective depressant for gangue minerals.

The rougher concentrates have been cleaned by applying an observation that the cassiterite in successive concentrates, obtained as more collector is added, becomes progressively coarser, and in each separate concentrate the tin is coarser than the gangue minerals. By sizing, salable grade concentrates have been obtained in good yield.

(*e*) *Rubber Reinforcement.*—The investigation of the function of fillers in rubber has continued. The production of reinforcing fillers from Australian raw materials could follow from a basic understanding of their function. The undesirable scorching properties of certain carbon blacks has been traced to their quinonoid structure and rapid copolymerization with the rubber matrix. The channel blacks, which are of the hydroquinone type, are probably slowly transformed to the quinonoid form during processing.

Work is now concentrated on the role of carbon black in imparting abrasion resistance to rubber.

(*f*) *Engineering of Adsorption Processes.*—Considerable progress has been made in the development of a continuous process for extracting uranium directly from an ore pulp. Pulps containing as much as 35 per cent. solids have been successfully passed through a bed of ion-exchange resin by jigging. Jigged beds of ion-exchange resins behave like a fluid in non-turbulent flow. This feature results in high extraction efficiencies and permits the resin particles, which have fully extracted the uranium and have therefore become heavier, to sink to the bottom of the bed where they can be continuously removed. A feature of the technique is that it may be used continuously or in batch operations.

A pilot plant for grinding, leaching, and extracting the uranium by a continuous ion-exchange process is under construction; financial assistance for the project has been given by the Australian Atomic Energy Commission. The South Australian Department of Mines has provided an officer to supervise the leaching operations.

(*g*) *Conservation and Use of Water.*—An investigation into the use of cetyl alcohol to retard evaporation of water from open storages has continued. Small-scale tests, out of doors, have continued with co-operation of the Division of Meteorological Physics, and have provided data leading to improvement in both the efficiency and effective life of the treatment. The results of these small-scale tests and of laboratory work were used to predict the conditions likely to yield satisfactory results on a large scale. During the summer of 1954-55, tests were performed on stretches of water varying between 1 and 320 acres in extent. Extremely heavy falls of rain covering a wide area spoiled most of these tests. The large-scale tests will be repeated during 1955-56.

A method for producing a potable water for stock from saline water is being sought. Processes undergoing development overseas for this purpose have serious limitations. A new electrochemical approach to the problem has been made but laboratory experiments so far have failed to produce useful results.

(*h*) *Chemical Nature of Chars.*—The aim of this project is to develop improved carbon adsorbent materials of industrial importance for such processes as purification of pharmaceutical products. Work so far has been confined to a study of the chemistry of chars in order to obtain better understanding of adsorption processes in these systems.

Studies, commenced earlier and concluded this year, have established the presence of quinone and hydroquinone structures in the simplest types of chars prepared from ash-free carbohydrates. The hydroquinone character of a char prepared at 400° C. is responsible for its ability to adsorb alkali, its reducing properties, and its ability to fog a photographic plate. The quinonoid structure of a char prepared at 800° C. accounts for the formation of peroxygen complexes, its ability to catalyse the ionization of oxygen, its oxidizing properties, and its reactivity with rubber. Chars prepared at intermediate temperatures acquire an intermediate or semiquinone characteristic. These findings seem to account for the major features of activated carbon and carbon black and may also be applied to coals and cokes. Thus it seems probable that a low-rank coal is analogous to a hydroquinone type char whereas a high-rank coal is essentially quinonoid.

(*i*) *Polyelectrolytes.*—There is a group of compounds whose molecules are large and which, because they can give a large number of charges (ionize), are soluble in water. These polyelectrolytes have attracted attention because of their ability to alter the structure of soil and so impart desirable qualities.

To provide basic information on the action between polyelectrolytes and the water in which they are dissolved, the activity of the water in polyelectrolyte solutions is being measured. It is intended also to attempt to use similar materials as waterproofing agents for soil, since work on control of evaporation has disclosed that the most serious loss of stored water in the Mallee area is by seepage.

(*j*) *Nitrogen Fixation.*—The mechanism of the reactions by which nitrogen of the atmosphere is converted to ammonia by certain bacteria and algae is being studied. This work is complementary to that being carried out at the Division of Plant Industry on the relationship between bacterium and host plant in root nodules which fix nitrogen.

Emphasis has been placed on the purification of the enzyme hydrogenase, and the study of its properties in comparison with those of certain simple systems which also react with hydrogen gas. Hydrogenase plays a part in nitrogen fixation, and is expected to have a structure related to that of the enzyme nitrogenase which combines with molecular nitrogen. The ultimate objective is to determine the structure of the prosthetic groups of these two enzymes, and the mechanism in detail by which they bring about the synthesis of ammonia.

A number of bacteria have been tested as suitable sources for hydrogenase and methods of assay investigated. The usual method using the dye methylene blue was shown to be invalid and a new technique using reduced methyl viologen proved successful.

(*k*) *Miscellaneous.*—A mathematical investigation of some problems of bulk and surface diffusion, which were also of interest to the Division of Tribophysics, has been completed.

6. Chemical Physics.

(Division of Industrial Chemistry.)

Work has continued on four main themes, namely (*a*) protein structure investigations, (*b*) the structure, energetics, and reactions of molecules, (*c*) the chemical physics of the solid state, and (*d*) the development of scientific instruments and techniques. Considerable collaborative and service work, centred around the specialized facilities of the Division, has been undertaken for industry, university departments, and other parts of this Organization. A number of guest workers, some undergoing training in specialized fields, have been accommodated in the laboratories during the year.

Professor N. S. Bayliss's co-operation and assistance in providing accommodation for and supervising vacuum ultraviolet spectroscopic work is gratefully acknowledged. Professor Bayliss has also undertaken to direct research on certain aspects of atomic absorption spectroscopy.

Particular attention has been paid to the stimulation of the manufacture of specialized scientific instruments in Australia. Several instruments, of novel principle and design, developed in the Division could be the basis of the initial production. At present two patents have been licensed to overseas instrument manufacturers; to date royalties amounting to 35,535 dollars have been paid for the use of one of these in commercial infra-red spectrometers.

(*a*) *Protein Structure.*—The object of this work is to obtain information on the structure of proteins, particularly the fibrous proteins, such as wool, hair, and muscle, and so lead to a clearer understanding of their mode of formation and function. This work, which includes the study of amino acids by X-ray methods, and the synthesis of polypeptides, is described in Chapter XVI., Section 10.

(*b*) *Chemical Physics of the Solid State.*—The study of the nature and properties of defects in solids and the way in which these defects influence physical phenomena and chemical reactions of solids has been continued.

In further studies of the optical properties of ionic solids, the experimental procedure has been refined and measurements of zinc sulphide have provided important information on the energy diagram of this solid. Theoretical calculations of the electronic energy states have also been undertaken and the implications of these in the interpretation of electronic phenomena in zinc sulphide examined. Photoconduction studies, which were being conducted in conjunction with these investigations, have assumed major importance because of possible far-reaching commercial applications.

The development of special-purpose electronic circuits has been a necessary step in the study of electronic processes in luminescent solids.

The study of solid-state reactions has proceeded. Oxidation processes on liquid metals have received particular attention experimentally. On the theoretical side the problem of aggregation of defects in a crystalline solid has been considered; this aggregation process is a crucial step in any solid-state reaction.

X-ray structural studies on dual-valency co-ordination compounds have been made and electron interference phenomena in lamellar crystals have been studied in relation to the structure of the crystals.

(*c*) *Molecular Structure Studies.*—Knowledge of the structure, energy states, and reactions of molecules and atoms is basic to much of chemistry and chemical industry. Their determination and study constitutes a major part of the effort of the Chemical Physics Section.

(i) *Structure Analysis by X-ray Diffraction Methods.*—The determination of the molecular structures of moderately complex organic compounds (e.g., important natural products) has been critically reviewed.

The analysis of aspartic acid hydrochloride, in the course of the programme on protein structure, has demonstrated significant errors in the tabulated scattering factors for the chlorine atom. Subsequent wave-mechanical calculations including exchange have confirmed the empirical results. The importance of a detailed study of the atom temperature factors for high accuracy has been stressed by this analysis.

The structures of even long-chain acids and alcohols have been correlated with the unusual intensity variations in their diffraction patterns.

The determination of the structure of partially dehydrated magnesium vermiculite has been completed.

(ii) *Structure Analysis by Electron Diffraction Methods.*—The structure of one of the phases formed when gas atoms are adsorbed on gold foil heated in air has been refined, and the probable structures and interrelation of several of the phases so formed have been established.

A complete analysis has been made of the structure of white lead, $2PbCO_3.Pb(OH)_2$. This is a disordered layer-lattice structure and its elucidation involved a further development of the technique of determining, and correcting the intensities for, the imperfect ordering. New techniques developed in the course of this structure analysis included the use of a modified Patterson function, and the use of patterns from tilted crystals to give "stereoscopic" three-dimensional pictures of the structure. The analysis also led to important conclusions on the influence of the phase shifts occurring in electron scattering on electron diffraction intensities and their use for structure analysis.

The structure of the intercalation compounds formed by ferric chloride and graphite has been studied.

A theoretical study has been made of the heating of thin films and small particles by the electron beams used in electron diffraction and electron microscopy. The conditions under which the use of pulsed beams is effective in reducing the rise in temperature without decreasing the visibility of the image on the fluorescent screen have been examined.

A new phenomenon in the imaging of objects with periodic structure was predicted theoretically and confirmed experimentally using an optical analogue.

(iii) *Spectroscopic Studies.*—The manner in which environment, such as that of solvent molecules, influences the energy states of a dissolved molecule has been studied in the simplest systems, the halogen molecules. The interpretation of the spectra of iodine and the computation of the potential energy diagram have been extended. The higher energy states of iodine and bromine are being studied by vacuum ultraviolet spectroscopy by an officer located in the Chemistry Department, University of Western Australia. Raman studies of halogen solutions have been initiated.

The infra-red study of *N*-substituted sulphonamides has been completed. Characteristic frequencies have been assigned for the sulphonamide groups.

(iv) *Molecular Ionization Potentials and Bond Energies.*—Electron-impact spectroscopy has been developed further for the measurement of the energy states of molecular and free-radical positive ions and for the estimation of bond dissociation energies, quantities of considerable relevance in chemistry.

On the experimental side, increased sensitivity has made possible the resolution of vibrational structure in electron-impact spectra of some molecular ions. An

ion source of special design and new methods of ion-current amplification have been devised as part of an attempt to achieve greater resolution by using mono-energetic electrons for bombardment.

The theoretical interpretation of electron-impact spectra has been extended. Profiles of peaks from fragment ions may be used to indicate whether or not kinetic energy is liberated during the ionization-dissociation process. Some progress has been made towards establishing collision mechanisms for the different processes of ionization.

(v) *Mechanism of Homogeneous Gas Reactions.*—The study of the mechanism of homogeneous gas reactions is of basic importance to many branches of chemistry. The measurement of free-radical concentrations in the reacting system is fundamental to any attempt to elucidate the mechanism of these reactions and this is being attempted for certain photolytic reactions. A new ion chamber, designed specifically for this work, has been fitted to the special-purpose mass spectrometer constructed in the Division. Preliminary experiments are in progress.

(vi) *Theoretical Studies.* — The conditions for validity of the electrostatic method of calculating molecular energies have been examined and the range of applicability of the general method extended.

(*d*) *Development of Chemico-physical Techniques.*—The success of much of the research in chemical physics depends on the development of new apparatus and new experimental techniques. For this reason, and to encourage production of specialized scientific instruments in Australia, considerable effort has been expended on this aspect of the Division's work.

(i) *Electron Microscopy.*—Several modifications have been made to the electron microscope; chromatic difference of magnification and rotation has been eliminated over a considerable part of the magnification range; the magnification range has also been extended. A new principle has been introduced into the design of ultramicrotomes and an instrument incorporating this is under construction.

(ii) *X-ray Diffraction.*—The design of an automatic Geiger counter goniometer has been completed and construction initiated. Further improvements have been made to the high-temperature adaptor for powder diffraction.

(iii) *Electron Diffraction.* — Some improvements have been made to the new microdiffraction camera following exhaustive tests of its operational characteristics. Various schemes for the measurement of the intensities of weak diffracted beams have been investigated, as future progress in the application of electron diffraction to structure analysis depends on this. A new, highly sensitive, gold-leaf electroscope has been designed and tested.

(iv) *Computers.*—A major programme is centred around the development of computing machines for various parts of the enormously time-consuming computations involved in structure analysis by X-ray and electron diffraction methods. Of the computers already designed, the construction of the image-seeking computer is well advanced.

(v) *Spectroscopy.*—The technique of spectrochemical analysis by atomic absorption spectra has been refined and extended. An English manufacturer of spectroscopic apparatus will manufacture under licence equipment similar to that developed in the Division. The prototype is now under construction.

The double-pass principle has been used to convert a Littrow spectrograph into a high-resolution recording monochromator. Raman equipment will also be converted to double-pass operation.

(vi) *Mass Spectroscopy.*—Factors governing sensitivity and efficiency in the performance of ion sources have been examined in detail and new sources have been constructed for several specific purposes.

Modifications have been made to the large mass spectrometer to permit operation as a differential instrument, and a new gas-introduction system and improved electrometer amplifiers installed; these improvements will permit the precise measurements of O^{16}/O^{18} isotope ratios for palen-temperature measurement.

(vii) *Electronic Instruments.* — Several electronic instruments having commercial possibilities have been developed in the course of the above research programmes. One is at present in commercial production.

(*e*) *Collaborative and Service Work.*—The specialized facilities of the Division have been made available through collaboration with and service to industry, universities, medical institutes, and other parts of this Organization. The scope and extent of this activity is illustrated by the following selection of the more important problems undertaken:—

(i) *Electron Microscopy.*—Extensive study of the structure and development of chloroplasts, the organelles of plants in which photosynthetic activity is centred; examination of *Rhizobium trifolii,* the microorganisms responsible for nitrogen fixation by leguminous plants; characterization of several clay minerals; examination of bacterial endospores of importance in problems of food preservation.

(ii) *Electron Diffraction.*—Structure of oxide layer on steel file blanks; structure analysis of graphite interlamellar compounds.

(iii) *X-ray Diffraction.*—Identification of hydrocarbons from *Kopsia Longiflora*; long-spacing determination of long-chain alcohols and acids from wool wax and carnauba wax; examination of long-chain diols from carnauba wax; identification of inorganic components of brown coal ash; assessment of structural complexity of $KCoF_3$; analysis of titanum dioxide samples; structure analysis of partially dehydrated magnesium vermiculite.

(iv) *Spectroscopy.*—Infra-red study of the structure of organic natural products, in particular, reserpine and alkaloids of the Jacobaea family; spectral transmissions of various filters and plastics; miscellaneous spectrochemical analyses; measurement of spectral output in P.P.I. tubes; infra-red spectroscopic measurements on numerous organic compounds, including isophthalic acid derivatives, certain iodo compounds, *cis-trans* isomers, anilides, and steroids; response tests on vacuum thermocouple detectors.

(v) *Mass Spectroscopy.*—Analysis of the gas filling in Geiger counter tubes to discover the cause of premature failure; detection and identification of volatile impurities in a number of samples; measurement of deuterium content of deuteronaphthalene samples; identification of products in organic reactions; tracer studies of the mechanism of cyanoethylation.

(*f*) *Instrument Laboratory.*—Major items completed during the period under review include—mass spectrometer ion chambers; gas-handling systems; vacuum pumps and vacuum systems of various kinds; development of compact hollow-cathode resonance sources; various specialized power supplies and amplifiers; a versatile frequency meter; development of technique for making helical glass vacuum gauges and helical quartz microbalances; electromagnetic lens for an electron microscope. The construction of the image-seeking computer and the development and construction of equipment for the production of diffraction gratings by the Merton method are well advanced. In the course of the latter project a new method for the production of bars of uniform diameter to high precision was developed.

7. Organic Chemistry.

(Division of Industrial Chemistry.)

The research programme is divided into the following main projects:—The investigation of the chemistry and possible utilization of wool wax and sugar-cane wax; the search for alkaloids of possible pharmaceutical value in the Australian flora and the examination of plants toxic to live-stock; the investigation of oils and fats, including the chemistry of long-chain compounds in general; and research on synthetic resins and plastics.

(*a*) *Constituents of the Wool Fleece.*—Work has been continued on the identification and estimation of the chemical constituents of wool wax and their conversion to commercially useful products. Similar work has been commenced on the organic constituents of suint, the mixture of water-soluble substances present in the fleece. This work is reported in Chapter XVI., Section 4.

(*b*) *Sugar-cane Wax.*—Crude sugar-cane wax can be resolved by treatment with a solvent into so-called resinous, hard, and soft wax fractions. The proportions and the properties of these fractions vary with the solvent and conditions used. The hard wax is the useful fraction. A variety of solvents have been examined for their performance in this resolution, and as a result two have been selected for more detailed study. Work in progress is aimed at developing a simple process by which to bleach the hard wax produced with either of these solvents.

One sugar-mill supplied regular samples of their fresh filter mud during the 1954 crushing season. The yield and properties of the crude wax in these samples were determined.

Further studies have been made of the effects of chemical modification on the properties of bleached sugar-cane wax. An attempt is being made to account for the differences in properties between the bleached wax and I.G. "Wax S". One important point seems to be the presence in the latter of high molecular weight dibasic acids, which are not found in the sugar-cane wax.

(*c*) *Carnauba Wax.*—The work on the constitution of carnauba wax has been continued, with the identification of seven omega-hydroxy-acids (C_{18} to C_{30}) representing the major portion (some 60 per cent.) of the acids from the wax.

(*d*) *Plant Alkaloids.*—The past year has seen a change in the approach to the survey of the Australian flora being carried out in the Division, in line with the reviving interest among the pharmaceutical industry in drugs of natural origin, including those from the higher plants. Systematic chemical studies in the plant kingdom have hitherto been few and very limited in scope, and the need to rectify this situation is becoming apparent. Negotiations are in progress with certain pharmaceutical firms with the object of putting the systematic pharmacological screening of Australian and New Guinea plants on a collaborative footing.

Among recent discoveries responsible for this renewed interest in naturally occurring drugs is that of the valuable hypotensive and tranquillizing agent—the alkaloid reserpine—from the Indian plant *Rauwolfia serpentina*. Examination of the small tree, *Alstonia constricta*, which occurs abundantly in southern Queensland and northern New South Wales, has now revealed the presence of this same alkaloid in the root bark, the content of some samples approaching 0.3 per cent. Provided a satisfactory commercial process for the separation of reserpine can be devised, *A. constricta* could become one of the most useful sources of reserpine. A number of Australian pharmaceutical firms are examining the possibility of production.

Work is in progress on other members of the family to which *Alstonia* belongs, the Apocyanaceae. In particular, structural studies with the alkaloids of *Kopsia longiflora* are sufficiently advanced to establish certain features not common to other apocyanaceous alkaloids. The Land Research and Regional Survey Section has supplied samples of a number of species from New Guinea, and certain of these show promising alkaloid content.

Progress has been made towards the synthesis of the vesicant alkaloid cryptopleurine, and a study of the stereochemistry of the methiodides of a number of quinolizidine bases is being undertaken to clarify the nature of the transformation of cryptopleurine to *iso*-cryptopleurine.

The structure of one of the alkaloids of *Lunasia amara* has been established, and the synthesis completed; it is a derivative of 2-phenyl-4-quinolone.

(*e*) *Stock Poisons.*—The main work in this field has again been concerned with plants containing pyrrolizidine alkaloids. The investigation of *Crotolaria retusa*, the cause of Kimberley horse disease, has continued with the assay of samples from Katherine, Alice Springs, and the Kimberleys, and the isolation of about a kilogram of monocrotaline for biological experiments. *C. retusa* has also yielded small amounts of three new alkaloids, the chemistry of which is under investigation. Studies on the alkaloids of *Senecio jacobaea* have reached a point where structures can be proposed for the main components. A common weed, *Erectites quadridentata*, has been found to contain the three known pyrrolizidine bases senecicphylline, senecionine, and retrorsine.

Investigation has begun of *Echium plantagineum*, which, despite its general acceptance as a non-toxic plant, has recently been suspected of causing liver damage to sheep in the Albury district, and three new alkaloids have been isolated. Work has also begun on *Amsenckia intermedia*, which is not under suspicion in Australia, but has been responsible for stock losses in the United States of America. The Queensland vine *Tournefortia sarmentosa* has been found to contain supenine, a minor alkaloidal constituent of heliotrope in substantial amount.

Much time has been devoted to the assay of new pyrrolizidine-containing plants, and the coverage of these assays is to be broadened to provide a clearer picture of the extent of alkaloid occurrence in this wide field. Of the 30 plants examined, sixteen contain more than 0.1 per cent. of base, inclusive of *N*-oxides. Six of eight *Crotolaria* species were in this category, and in view of the wide distribution of this genus in northern Australia and the difficulties involved in feeding trials, a detailed study of the genus is to be made.

Further work has been done with the major alkaloid of the seed of Western Australian blue lupin. It is evidently an unrecorded keto-sparteine.

In the non-alkaloidal field, work continues on *Atalaya hemiglauca*, *Indigofera enneaphylla*, and *Phalaris tuberosa*. Recent overseas work showing that β-nitropropionic acid is the toxic principle of *Indigofera enneaphylla* suggests that it may also be responsible for the toxicity of *I. enneaphylla* in horses. A quantity of the acid has been synthesized for biological testing.

Lack of seasonal growth of experimental *Phalaris tuberosa* pastures prevented any progress with the projected study of phalaris staggers, but fractionation of extracts of phalaris from Tooradin in the search for a component having curariform activity has proceeded. The active material is now known to be acidic. Fractionation of aqueous extracts of the seed of *Atalaya hemiglauca* has yielded concentrates toxic to guinea pigs.

(*f*) *Chemistry of Tallow Constituents and Long-chain Aliphatic Compounds.*—Work on the chemistry of oleic acid has been continued with the study of the

ketonization of this and related unsaturated acids. The substance described as oleone in the literature has proved to be a mixture containing mainly other (*trans*-oriented) ketones. It has not been possible to prepare pure oleone from oleic acid by the direct methods reported to be applicable, but indirect procedures by way of the acid chloride or ester have succeeded. Pure oleone is a low-melting solid. This and other related ketones can be readily converted by oxidation to keto-dibasic acids.

A project aimed at the oxidation of long-chain fatty acids at specific points in the chain has been commenced.

In collaboration with the Dairy Research Section, the synthesis was undertaken of three long-chain aliphatic diene aldehydes, of the type responsible for flavour defects in milk. These aldehydes have not previously been recorded in the literature.

(*g*) *Investigation of Potential Seed Oil Resources.*—The investigation of Australian samples of *Mallotus philippinensis*, which yields an interesting unsaturated seed fat to which much attention has recently been devoted in India as a possible replacement for tnng oil, has been continued. The material of Australian origin has been shown to be comparable in quality with the Indian, but samples of the seed were found to be very variable in respect to yield of fat. A preliminary assessment of the possibilities of commercial exploitation has been made.

The seed fats of three *Santalum* species have been examined: the sweet and bitter quandongs, and the fragrant sandalwood (*S. acuminatus*, *S. murrayana*, and *S. spicatus*). These fats are all rich in ximenynic acid (an acetylenic acid), but unlike the seed fats of certain *Ximenia* species, do not contain higher unsaturated fatty acids, oleic acid being their major constituent.

(*h*) *Synthetic Resins and Polymers.*—(i) *Tigaso Oil.*—This oil, which is exuded when the wood of the New Guinea tree *Campnospermum brevipetiolatum* is cut, has been fractionated on alumina both before and after hydrogenation and hydrolysis. An optically active componnd has been isolated which is non-phenolic, in contrast to the major constituent of the oil, campnospermonol. Work on the chemical constitution of this new compound is proceeding.

In co-operation with an interested industrial organization, a start has been made on evaluating the resins which can be formed from tigaso oil.

(ii) *Cyanide Polymers.*—The insoluble polymeric material which forms at the anode when a cyanide is electrolysed in aqueous solution is being studied. The material, which is insoluble in most solvents, appears closely related to but not identical with "paracyanogen", prepared by thermal decomposition of mercuric cyanide under pressure. It is also similar to the polymer formed from hydrocyanic acid on standing in the presence of alkali. The cyanide polymer is not the only product of electrolysis; one of the more interesting which has been isolated is cyanuric acid.

(*i*) *Microanalytical Laboratory.*—Demands on the services of the Microanalytical Laboratory, run by the Division in conjunction with the University of Melbourne, continue to increase. Over 5,000 individual analyses have been performed in the past year, an increase of 10 per cent. over the previous year; of these approximately 60 per cent. were for C.S.I.R.O. and other Commonwealth Laboratories, 35 per cent. for universities, and 5 per cent. for industrial laboratories. Of particular interest is the increasing number of requests for analyses from universities outside Australia. In addition to the range of standard analyses, facilities for the determination of microsaponification values are now available. Special analyses performed include silicon and fluorine in organic compounds.

8. Chemical Engineering.

(Division of Industrial Chemistry.)

The major part of the research programme is associated with the utilization of brown coal, particular attention being given to the study of the techniques and chemical reactions which are of importance to brown coal gasification.

Other research projects are concerned mainly with the investigation of the characteristics of fluidized solids and the application of the fluidization technique to the roasting of minerals and concentrates. Over the past five years the Division has accumulated a wide experience in this field, and requests for advice and assistance are constantly being received from companies who are interested in the application of fluidized methods of processing in their industrial operations.

The Division's Process Equipment Laboratory provides a service to industry and to other parts of the Organization by maintaining and supervising the use of a wide range of pilot-scale chemical processing equipment, which is made available for short-range process investigations or for the preparation and treatment of batches of special chemicals.

(*a*) *Coal Utilization.*—Both fundamental and applied studies of the gasification of brown coal have been continued. These are described in Chapter XX., Section 6.

(*b*) *Fluid Bed Roasting of Copper Concentrates.*—Investigations of the roasting of copper concentrates in a large fluidized-bed, pilot-plant roaster have reached an advanced stage. This work was undertaken at the request of Mt. Morgan Ltd. and the Mt. Lyell Mining and Railway Co. Ltd., and is carried out in collaboration with these companies. The main purpose of the work is to determine the feasibility and optimum conditions for a proposed hydrometallurgical process for the recovery of copper and precious metals from sulphide concentrates. This process consists in controlled roasting of the concentrates to convert the copper into a form soluble in dilute sulphuric acid, the leaching of the calcines, and the electrode position of the copper from the leach solutions. The precious metals which remain in the residnes after leaching may be recovered by cyanidation. Information is also being sought to permit the evaluation of fluidized bed roasting as a means for production of calcines for reverberatory furnace and electric arc smelting.

The fluidized bed roaster which has been installed is of 3 ft. 6 in. internal diameter, and has a capacity of about 3 tons/day of concentrates. In the early stages of this work it was necessary to spend considerable time in solving the difficult problems involved in feeding the copper concentrates to the roaster, in the form of a slurry of 75-80 per cent. solids content, at a constant and reproducible rate. An ingenious type of pump was finally developed for this purpose.

At the present stage in the investigation a great deal of valuable information on the influence of operating conditions on the composition and properties of the calcines has been accumulated, and it is possible to specify with fair accuracy the optimum conditions for the production of a calcine of a given type. However, a serious problem, in the agglomeration of calcines in the roaster, has been encountered. This agglomeration may cause defluidization of the bed and formation of troubleseme deposits on the roaster walls. Efforts to solve this problem have shown that it is associated with a high copper content in the calcines, and thus may be avoided by restricting the grade of concentrates to be roasted. However, it has also been shown that by careful design of the air distributor it is possible to mitigate the troublesome effects of agglomeration, even with calcines of high copper content.

(*c*) *Process Equipment Laboratory.*—This laboratory provides facilities for technological experiment and the rapid development of chemical processes to the

pilot-plant stage. It also facilitates certain types of fundamental investigations where the initial steps may involve quantities of natural materials that are too large to be handled in conventional laboratory equipment.

Most of the work done originates in other Sections of the Division, in other Divisions of the Organization, or in private firms. The laboratory furnishes the equipment and advises on its use, but the collection of data is left to the staffs of the particular organizations who make use of this service.

In the past year, four plants have been advanced to the pilot stage of development, special processing equipment was used for test purposes on eighteen occasions, and some eighteen extractions were carried out preliminary to laboratory investigations.

9. Radio-active Tracer Elements.

(Tracer Elements Investigations.)

The Unit has continued to help research workers who wish to use radioactive tracers. This assistance included collaboration with the Chemistry Department of the University of Melbourne in giving a Radiochemistry Course of one week's duration in June.

The main work undertaken comprised:—

(*a*) *Isotopic Tracers in the Study of Chemical Reactions.*—(i) Tracer techniques are being applied to a study of the pinacol re-arrangement. A preliminary to this work was a thorough investigation of the kinetics of the re-arrangement; this is now complete. ^{14}C-labelled pinacols have been prepared and the isotope effect in the re-arrangement is being determined.

(ii) Radioactive tracer methods are being used to analyse products formed by the action of ionizing radiation (X-rays and ^{60}Co gamma radiation) on benzoic and salicyclic acids labelled with ^{14}C.

(*b*) *Collaborative Work.*—Experiments carried out with the Wildlife Survey Section led to a satisfactory method of tagging carrots with radioactive iodine. This method is suitable for the study of the feeding habits of rabbits in field experiments.

In collaboration with the Division of Animal Health and Production, the fate was determined of ^{35}S-sulphate in two sheep, in one of which a high level of molybdenum in the blood was maintained. This work is related to a study of the way in which molybdenum and sulphate affect copper deficiency in sheep. In connexion with the same problem a method for the determination of sulphate in pastures by isotope dilution analysis was developed.

(*c*) *Synthesis.*—The synthesis of 2-^{14}C-methyl-4-chlorophenoxyacetic acid ("Methoxone") has been completed. The mode of action of this plant growth regulator is now being studied by the Division of Plant Industry.

(*d*) *Radioactive Assay Methods.*—Work has continued on the development of gas counting of ^{14}C, scintillation counting, and autoradiography. An instrument for the automatic measurement of radioactivity on paper chromatograms was constructed and is now in routine use.

XIX. MINERAGRAPHY AND ORE-DRESSING.

1. General.

The importance of investigations for the development of the mining industry and the utilization of Australia's mineral resources is fully recognized by the Organization.

Mineragraphic work to provide information on the mineral composition of ores has been in progress in Melbourne since 1927. The techniques used are highly specialized and require considerable experience, so that it is only rarely that they can be applied by the staffs of operating mines. The current work of the Mineragraphic Investigations Section is described in Section 2 of this Chapter.

The Ore-dressing Laboratories operated in Melbourne in collaboration with the University Department of Mining, and in Kalgoorlie in co-operation with the School of Mines, investigate the composition of ores and provide advice on suitable methods for their full-scale treatment. This work is reported in Sections 3 and 4 of this Chapter.

Work on the utilization of minerals is carried out by the Division of Industrial Chemistry (*see* Chapter XVIII., Section 2).

2. Mineragraphic Investigations.

(Mineragraphic Investigations Unit.)

Thirty-seven investigations have been made of the mineral associations of rocks, drill cores, and mill products submitted by mining companies and other organizations. A number of these were related to the search for new mineral deposits. Twelve were concerned with uranium ores. Eight were concerned with experimental treatment of ores in the Ore Dressing Laboratories, and three were submitted by the Minerals Utilization Section, Division of Industrial Chemistry.

Examination of uranium ores from the Mary Kathleen lease, Queensland, revealed the presence of a new mineral, identified with the help of the Mineral Utilization Section, as a rare-earth borosilicate, and named stillwellite, after Dr. F. L. Stillwell, former head of the Section. A specimen from Rum Jungle, Northern Territory, resembling torbernite, but showing anomalous fluorescence, was found to consist of a microscopic interlayering of plates of meta-torbernite (non-fluorescent) and meta-autunite (fluorescent). Uraninite was identified at Mary Kathleen, Queensland, and Ravensthorpe, Western Australia; and pitchblende was found at Fleur de Lys, Brocks Creek, Northern Territory, and at Rum Jungle, Northern Territory. Brannerite was identified at leases in the Mount Isa district, Queensland, and a number of bismuth, nickel, and cobalt minerals were identified in Rum Jungle ore.

Cobalt ores from Mount Cobalt mine, Selwyn, Queensland, and the Cambourne lode, Mungana, Queensland, were examined, and an intensive study was made of the mineral composition, at all levels, of the Peko copper ore body at Tennant Creek, Northern Territory. This, in addition to copper, contains gold, bismuth, and cobalt minerals. A little wolframite and some primary goethite were found also, indicating a wide temperature range during deposition of the ore.

The occurrence and grain-size distribution of the gold in the ore of the Hill 50 Gold Mine, Western Australia, were investigated.

A detailed petrological and mineragraphic study was completed of the scheelite deposits at Grassy, King Island, Tasmania. This revealed the great variety of rock types present, and the intense but localized metasomatic changes that accompanied deposition of the ore. It also provided a basis for correlating the rocks containing the ore bodies with other geological formations on the island.

A survey was made, in conjunction with the Broken Hill Geological Research Committee, of the distribution of cadmium in the Broken Hill Lode. The cadmium occurs substituting for zinc in the sphalerite of the lode, and a distinctive pattern of zinc:cadmium ratios was found in zinc concentrates prepared from different sections of the various ore bodies comprising the lode. The zinc:cadmium ratios appear to increase with the progress of deposition of the ore.

An extensive investigation of the composition of beach sands in the Portland district of Victoria was undertaken for the Portland Harbour Trust, in an attempt to determine the direction and amount of sand drift in the harbour region. The first half of the investigation is complete, and indicates that sand drift is likely to be local only. Indicator minerals have now been added to the beaches, and their movements are being followed.

The Section's investigations have been facilitated by increased contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has co-operated in providing laboratory accommodation.

3. Ore-dressing Investigations

(Melbourne Laboratory.)

During the first quarter of 1955 the Section transferred to the new building which has been erected to house the University Mining and Electronics Departments and the Ore-dressing Section. Although the move involved temporary disruption of routine, the greater space now available and the improved facilities are already most beneficial.

New equipment acquired during the year includes a second autoclave for work on pressure leaching at rather high temperatures and pressures, a Knapp and Bates laboratory pneumatic table for dry gravity concentration, and a 6-in. by 4-in. diaphragm jig which was designed and constructed in the laboratory.

Investigations during the year included work on ores of antimony, cobalt, gold, lead, manganese, silver, tantalum-columbium, tungsten, uranium, and zinc, and on beach sands, diamonds, and phosphate rock.

Three antimony ores were concentrated by flotation, and although stibnite was the principal mineral involved in each case, each ore needed rather different flotation conditions. One merely needed the addition of a higher xanthate to obtain good recovery, another needed an optimum addition of activator, and the third needed stage additions of activator and collector for best results. A plant has been erected in New South Wales to treat one of these ores.

Interest is being maintained in cobalt ores and investigations into general methods of treatment are continuing. Test work confirmed that electrostatic separation was not likely to be useful in the treatment of cobalt-manganese oxide ores. Leaching of such ores is to be further investigated and work on the gravity and flotation concentration of an ore containing cobalite and erythrite is in progress.

An investigation in collaboration with the mine staff of Morning Star (G.M.A.) Mines N.L. has been carried out to determine a satisfactory method for destroying cyanide in plant residues and discharged effluent. The mine is situated in mountain country within the watershed of the Goulburn River. Satisfactory results have been obtained with a method involving the use of ferrous sulphate and bleaching powder.

Treatment of a gold ore from Queensland was complicated by the presence of a high proportion of arriferous sulphides and some copper minerals. The work done showed that for high gold extraction, extensive plant would be required as the process would involve bulk flotation of a sulphide concentrate for roasting, acid leaching and cyaniding, together with cyanidation of the flotation tailing.

Treatment of an oxidized lead-silver-gold ore from Queensland was investigated and good recovery of lead obtained by gravity concentration after roll crushing of the ore. Satisfactory gold recovery was obtained from table concentrates and coarse table tailing by cyanidation. A feature of the ore was the large proportion of primary clay slime for which no really satisfactory treatment process was devised.

Further work on the electrostatic concentration of alluvial diamonds was carried out. The work was done on a product from a dredge-borne jig, which contained quartz, some iron oxides, and other minor minerals. It was found that if such a product was mildly agitated, when dry, the quartz become selectively more conducting, presumably due to an electrostatically conducting coating of iron oxides, and that diamonds could be concentrated in a very small bulk of less conducting product.

4. Ore-dressing Investigations.

(Kalgoorlie Laboratory.)

At Kalgoorlie, where work is done in co-operation with the School of Mines, sixteen Reports of Investigations and 52 Certificates (assays, analyses, and similar work) were issued. Of the Reports, nine had reference to gold ores, four to the ores of other metals, two to non-metallics, and one to the possible use of a commercial detergent as a flotation reagent. The Certificates referred mainly to assays and analyses of various ores and minerals, and nearly all Certificates contained results from a number of samples.

Installation of a pilot plant capable of treating from 100 to 200 lb. of ore per hour was completed, and trial runs were held. The plant contains the following sections: grinding, thickening, classification, flotation, filtration, cyanidation, and gravity concentration, and is designed for continuous operation. The large units are installed in fixed positions, but other units are mobile and can be used as required.

Methods of treatment were developed for the three main ore types from the Lancefield N.L. Gold Mine at Beria. Fine grinding and "straight" cyanidation gave respectively 95 and 86 per cent. gold recovery from the oxidized and semi-sulphide ores, but the sample of heavy sulphide ore required flotation and roasting of the concentrate for a satisfactory gold recovery.

Heavy-media separation tests on a Kalgoorlie gold ore were unsuccessful in producing a "sink" or "float" prodnct, of sufficiently low grade to be discarded.

Hill 50 Gold Mine ore types were examined in conjunction with the Mineragraphic Investigations Section to determine any essential differences in ore character. The ore types submitted, although they varied greatly in gold value, were all essentially of the same character.

Accumulated flotation tailings from the Blue Spec Mine gave a recovery of about 60 per cent. of the gold and the scheelite after cyanidation and gravity concentration.

Heavy-media separation of a gold-stibnite ore from Victoria at 1.5 inches maximum size gave a recovery of 2.3 per cent. antimony from a head value of 2.6 per cent.

Cyanidation tests on a high grade gold stibnite ore sample showed that ammonium persulphate increased the gold recovery by cyanidation from 50 to 90 per cent.

Research into the possible use of a detergent as a flotation frother indicated that it was of no value in sulphide flotation but may be of value in non-metallic flotation.

Heavy-media separation tests on a spodumene ore from Coolgardie gave excellent recovery (62.6 per cent.) of the mineral from felspar. The concentrate assayed 5.5 per cent. lithium.

Fluid-bed test work in the cold was carried out on a sample of beneficiated lime sands from Perth. Further work at elevated temperatures is proceeding on this material.

XX. FUEL.

1. General.

The Organization's fuel research programme is at present mainly confined to coal. There is insufficient knowledge concerning the properties and characteristics of Australian coals and an urgent need for this knowledge exists so that the best and fullest use may be made of the available resources.

The Organization's main centre for investigations on fuels is the Coal Research Section, located at North Ryde, New South Wales. This Section was established to undertake a fundamental and comprehensive study of the physical and chemical characteristics of Australian coals. The work of the Section is reported in Sections 2-4 of this Chapter.

The Division of Industrial Chemistry undertakes work on the engineering aspects of gasification of low-rank coals, and this is reported in Section 6 of this Chapter.

Co-operative investigations on the fossil pollens in brown coal are undertaken in the Botany School of the University of Melbourne, and are reported in Section 5 of this Chapter.

The Organization's Central Experimental Workshops at Maribyrnong, Victoria, are studying the design and construction of solar water heaters for domestic and industrial applications, and this work is reported in Section 7 of this Chapter.

Coal Research Section.—Coal is the most important solid fuel available in Australia and the programme of work of the Coal Research Section covers *inter alia* a detailed survey of the chemical and physical properties of indigenous coal seams; coal washing and allied investigations to effect an improvement in the coking properties, or a reduction in the sulphur and ash contents of coals, or both; the carbonization, gasification, and combustion of solid fuels; fundamental studies in the petrological and chemical constitution of coal; standardization of sampling, sizing, testing, and analytical techniques as applied to solid fuels.

Whilst concerned with long-term problems associated with the evaluation of coal resources on a national basis, the work of the Section is designed to bear directly on current and future problems of coal utilization. Considerable progress has been made towards establishing the facilities required for programmes already commenced, and the activities of the Section continue to expand as staff is trained and equipment obtained.

Pilot-scale carbonization plant, combustion furnaces, equipment for testing the mechanical properties of coal, and large-scale plant for investigating the washability characteristics of coals are now in operation.

During the year a pot furnace to simulate combustion processes in overfeed fuel beds was completed and operating techniques were established. A pilot-scale slot oven for the investigation of carbonizing conditions and of coal blending for the production of foundry coke was also completed.

The Section has conducted carbonization, combustion, and washability tests in connexion with specific inquiries for new plant and equipment, and increasing use is being made by industry of the results of such investigations in the design and selection of suitable plant.

The efficient utilization of both low-rank and low-grade coals is of considerable importance in the economic development of secondary industries throughout the Commonwealth and, within the limits and capacity of available staff, increased attention has been given to investigations concerned with the burning of such fuels.

Officers of the Section continue to make a major contribution to the activities of the Institute of Fuel (Australian Membership). Over 80 reports dealing with the Section's investigations were prepared during the year, and a large number of technical inquiries were answered.

Mr. N. Y. Kirov paid a short visit to the United States in order to attend the Joint International Conference on Combustion at the Massachusetts Institute of Technology.

In his capacity as Australian member of the Commonwealth Committee on Fuel Research, the Officer-in-charge continues to act as co-ordinator of reviews of fuel research carried out by official fuel research centres throughout the British Commonwealth and dealing with (*a*) physical testing of coal and petrographic investigations, and (*b*) brown and sub-bituminous coals.

Towards the end of the year, Dr. D. T. A. Townend, C.B.E., Director-General of the British Coal Utilization Research Association, spent three months in Australia advising the Organization on its coal research programme. Dr. Townend made his head-quarters in Sydney and the staff of the Coal Research Section derived considerable benefit and inspiration from discussions with him.

With the ready assistance and co-operation from colliery proprietors, large coal users, and State authorities, Dr. Townend had important discussions and made extensive visits of industrial areas in New South Wales, Queensland, Victoria, and South Australia, and his visit has been of the greatest value, not only in providing an independent assessment of the Section's work, but also in promoting closer contact with the coal-producing and coal-using industries.

2. Examination of Coal Seams.

(Coal Research Section.)

Survey work for the year under review has been confined to seams in the upper and lower coal measures in the Northern Coal-field of New South Wales, and work on the Greta (lower coal) measures in the Maitland, Cessnock, and Muswellbrook areas is continuing. Coals from the Muja open cut (Western Australia) and from Leigh Creek (South Australia) have also been examined—the former in collaboration with Broken Hill Proprietary Company Limited, and the latter through the courtesy of the State Electricity Trust of South Australia. The assistance of these organizations is greatly appreciated.

Reports dealing with the examination of some 23 bores sunk by the Joint Coal Board in the Balmoral area (south of Muswellbrook) have been prepared. The testing and analysis of cores recovered in a bore hole sunk by the Broken Hill Proprietary Company Limited, and passing through 820 feet of strata while penetrating the Young Wallsend, the Yard and the Borehole seams, was commenced.

3. Coal Constitution.

(Coal Research Section.)

(*a*) *Petrography.*—Petrographical studies form an important part of the investigations into the chemical, physical, and mechanical properties of coal, and of its behaviour under various conditions such as storage, grinding and carbonizing.

Study of the petrographical structure of New South Wales coal seams has continued both by the use of thin sections using transmitted light, and of polished sections using incident light.

Investigations of the possibility of using the distribution of certain microspores for the purpose of intercorrelation of coal basins and individual seams is being continued. A systematic examination and classification of the bisaccate microspores isolated from

coals and shales of the Australian Permian has been made, and their structure and distribution have been studied. Comparisons have been made between Australian Palaeozoic bisaccate forms and similar types from approximately contemporaneous deposits in other parts of the world.

Isolated monolete, monocolpate, and alete sporomorphs have been found to occur frequently in Australian coals and shales of Permian age. The structure, distribution, and possible affinities of a number of the more common types has been studied, and they have been classified on the basis of their germinal mechanism and ornament.

The officers engaged on this highly specialized and exacting work have been called upon to carry out palynological examinations to assist in determining the age and correlation of strata encountered during the drilling for oil in Western Australia and in New South Wales.

(*b*) *Physical and Chemical Properties.* — (i) *Thermal Investigations.*—An apparatus was assembled for the determination of low-temperature nitrogen absorption isotherms and helium densities. The surface areas of seven coals having carbon contents ranging from 93 to 68 per cent. (d.a.f.) were determined from their isotherms, using B.E.T. equation. The surface areas were small (less than 10 sq. m. per g.) for coals with carbon contents of less than 90 per cent., but that of semi-anthracite was much higher; there was no simple correlation of the surface area with rank of coal.

An investigation of the effect of temperature upon the heat of immersion in water of several coals indicated that there was no change in the range 4-40° C. An increase in the heat of immersion with increase of temperature was found, however, in the one case in which powdered coal had been stored in a sealed container for some months before being used for the measurements.

During an investigation of the change in the surface area of coals during pyrolysis (measured by the B.E.T. method at low temperature), it was found that a very marked increase in the internal surface takes place between 400 and 600° C. This was particularly noticeable in a char derived from brown coal.

(ii) *Refractive Indices.*—The refractive indices of a wide range and type of coals were determined using the Brewster angle method and by immersion of pulverized samples in liquids of known refractive index. The two methods gave comparable results in most cases, but the latter is more convenient and accurate.

It proved possible to determine the refractive indices of fusain found in brown coal, and of chars obtained by heating brown coal up to 350° C.

(iii) *Chemical Properties.*—Vitrains from high-rank coal were found to be entirely soluble in boiling phenanthrene, the solubility diminishing with caking power. If the benzene-soluble portion of the extract was removed the residue would not form a coherent coke.

Non-acidic oxygen groupings (apparently quinone groups) which were converted to phenolic groups under mild reducing conditions were found in cokes and chars formed at 450-500° C. In the case of a sample of vitrain from the Lithgow seam (carbon content 83 per cent.) the main thermal decomposition occurred between 400 and 500° C. and, in this range, approximately half of the phenolic groups present in the original were converted to non-acidic oxygen groupings. It appears that, during carbonization, dehydrogenation of phenols occurs with the formation of quinone groups.

The acidic groupings in a large number of coals were determined by means of titration in anhydrous ethylenediamine, enabling the proportion of acidic and non-acidic oxygen groupings in the coals to be calculated. The changes in these groupings during oxidation, carbonization, or treatment with various reagents, has been studied using a brown coal and a bituminous coal of medium rank.

From preliminary experiments indications have been obtained that about 20 per cent. of the nitrogen in coal is in the form of basic groups accessible to titration in anhydrous solvents.

Changes in the infra-red spectra of coals produced by carbonization at varying temperatures and by chemical reactions were observed using specimens as mulls in liquids or as disks made by pressing mixtures of coal and potassium bromide. The changes in chemical groupings observed by this technique showed excellent correlation with the results obtained by titration in non-aqueous liquids.

4. Coal Utilization.

(Coal Research Section.)

(*a*) *Combustion Investigations.*—(i) *Surface Ignition in Fuel Beds.*—The influence of some factors on the propagation of surface ignition in fuel beds has been investigated. It was found that the addition of surface moisture promoted a more stable and uniform fuel bed but retarded ignition, whereas fines (below $\frac{1}{8}$ inch) conditioned to as much as 21 per cent. surface moisture were no more difficult to ignite than a closely graded $\frac{3}{4} \times \frac{1}{2}$-in. air-dried coal. A considerable amount of experimental evidence is available to show that modern mechanical stokers of the travelling grate type can burn, without loss of efficiency, fuels containing an appreciable quantity of fines (below $\frac{1}{8}$ inch), provided they are suitably moisture conditioned.

(ii) *Burning in Industrial Boilers.*—In the burning of low-rank coals in industrial boilers, certain difficulties are experienced which result in excessive combustion losses and reduced steaming capacity, when compared with good-quality steam raising coals. During pilot-scale utilization studies of Leigh Creek coal it was found that efficient combustion in the size range 1 to $1\frac{1}{2}$ inches (the maximum size tested) was difficult to achieve, and that initial ignition was retarded owing to large size, high moisture content, or high ash content of the feed. When crushed to below $\frac{1}{2}$ inch the coal could be burned with reasonable efficiency, but only at relatively low rates of primary air flow and with low rates of heat release. Optimum conditions were obtained with rates of primary air supply below 300 lb. per square foot per hour, giving a maximum net heat release of just under 3 therms per square foot per hour. Similar investigations were made with coal fines and washing slurries which were burnt in the raw state and also in the form of pellets.

(*b*) *Carbonization Studies.*—(i) *Tests in Carbonizing Plant.*—In continuation of the evaluation of the gas-making properties of Australian coals over 40 tests have been carried out on a pilot-scale carbonizing plant. Coals have been carbonized at temperatures ranging between 600 and 1,000° C., and for periods of between 9 and 36 hours.

A series of tests was commenced to determine quantitatively the extent of the deterioration of coking and gas coals on storage, the initial programme being designed to cover storage periods of from 2 to 52 weeks.

(ii) *Coke from Bulli Seam Coal.*—In a preliminary study of factors affecting the production of metallurgical coke from the Bulli seam coal, the following investigations were carried out:—

(1) *The Measurement and Control of the Bulk Density of Coal Charges.*—Three methods for the determination of bulk densities were compared, namely, the Kopper's cone method, the 6-ft. drop test, and vibrational packing. The variation of the bulk densities on wetting coal samples with various amounts of water,

from 2 to 10 per cent. by weight, was determined by these methods. The effect of small oil additions, 0.2 to 0.6 per cent. by weight to the wetted samples, was also measured. The oil additions were found to reduce the bulk density variation due to wetting, and can be used as a means of stabilizing and controlling the densities of coal charges for carbonizing. Information was also obtained on the angle of repose, and the handling and flow properties of crushed coal with different moisture contents. A report is in preparation.

(2) *The Effect of Variation in Charge Density on the Carbonizing Behaviour of Coal and Quality of the Resulting Cokes.*—Samples of different charge densities, controlled by moisture additions, were carbonized in the B.M.-A.G.A. plant under comparable conditions. From observations of the carbonizing behaviour and measurement of the physical properties of the cokes, it was possible to specify optimum charging conditions. A report is in preparation.

(3) *The Effect of Blending Petrographic Fractions on Coke Quality.*—It was observed that natural breakage of the coal during mining and other handling operations resulted in the accumulation of vitrain in the finest sizes of the run-of-mine. This constituent, generally present in the seam as thin bands, is very brittle and, as plastometric measurements showed, highly plastic and swelling during coking. The extent of this partial petrographic segregation was revealed quantitatively by petrographic and plastometric measurements. A series of blend experiments was designed, in which blends in various ratios of vitrain-rich fine coal with large crushed coal consisting mainly of durain and relatively low in plastic and swelling properties, were carbonized. From the results of these carbonizations in the B.M.-A.G.A. plant, recommendations were given for the best way of selecting and preparing portions of the run-of-mine coal most suited to the production of metallurgical coke.

(4) *The Effect of the Addition of Coke Breeze to Coal Charges for Carbonization.*—In a series of experiments similar to the above tests, the effect of blending various amounts of coke breeze with the raw coal charge on the quality of the resulting cokes was examined. It was found that the addition of a small amount (about 3 per cent.) of coke fine had a beneficial effect and improved the physical and mechanical characteristics of the coke.

(iii) *Tars.*—As an essential part of the above carbonization studies, the properties and constitution of tars obtained during the pyrolysis of coal on a pilot-plant scale are being investigated, and correlations made with tars produced during the industrial operation of gas-making retorts and coke ovens.

Methods of estimating the constituents of tar, for example, naphthalene, phenanthrene, carbazole, and anthracene continue to be investigated with a view to developing speedier and more accurate procedures.

The carbonization of some Australian coals in continuous vertical retorts results in tars yielding naphthas of boiling range 136 to 156° C. These naphthas contain about 10 per cent. of styrene. Tar distillers have had difficulty in polymerizing this styrene with catalysts such as benzoyl peroxide, sulphuric acid, and aluminium chloride. Laboratory investigations have shown that the cationic catalysts boron trifluoride-acetic acid complex or boron trifluoride-hydrogen fluoride-fluorboric acid mixture promote complete polymerization of the styrene in the naphthas and give very viscous oily products which, on further distillation, leave solid amber-coloured resins.

Co-polymerization of the styrene (in naphtha solution) with indene fractions from the same tar gives theoretical yields of solid co-polymers similar to coumarone-indene resins, having higher softening points than the styrene resins.

(iv) *Petrographic Analyses.*—In connexion with the carbonization and coal preparation investigation summarized above, petrographic analyses of several seams and of coal blends have been carried out by counting or measuring (or both) the several coal components under the microscope with the help of an integrating stage. In coal from one seam, the average ash content of which was over 13 per cent., it was found that 40 per cent. of the coal in the fraction less than $\frac{1}{4}$ inch had a specific gravity of 1.3 and yielded 2.2 per cent. of ash on incineration. The fraction, consisting mainly of vitrain, had exceptional coking properties. A considerable portion of the Section's resources is concerned with investigating how these enrichments, already present to some degree in coal as mined, may be increased artificially by making use of the different degrees of hardness, brittleness, and fracture exhibited by the various coal macerals. The blending and carbonizing for the production of metallurgical coke of the fractions of coal components thus concentrated constitutes a major item in the Section's current programme.

(*c*) *Washability Studies.*—In connexion with the carbonization work summarized above, the washability characteristics of the Bulli and Wongawilli seams were investigated. The samples were drawn from Coal Cliff Colliery and Port Kembla No. 2B Colliery respectively.

With the Bulli seam from this locality it was found that coal larger than $\frac{1}{8}$ inch contained about 14 per cent. of total ash, of which 8 per cent. is not removable by mechanical cleaning processes. Coal less than $\frac{1}{8}$ inch had a total ash content of 11 per cent. The $+\frac{1}{4}$-in. coal could be reduced from 14 to 10 per cent. ash content by separation at a specific gravity of 1.5, with a recovery of 90 per cent. of the raw material as clean coal and a reject containing 50 per cent. ash. Within the specific gravity range of 1.5-1.7 there is only about 4 per cent. of the total raw coal, so that cleaning could easily be accomplished at operating gravities within this range.

The sample of Wongawilli seam presented a very difficult cleaning problem. The specific gravity of the seam plies varied from 1.36 to 2.44, and whilst the very fine coal (minus 30 B.S. mesh), amounting to 17.5 per cent. of the output, had an ash content of 10.1 per cent., the run-of-mine coal had an ash content of 26.8 per cent., only 62 per cent. of which could be separated at an operating gravity of 1.6 to give a cleaned coal product of 15.5 per cent. ash content.

Analysis of an investigation of the rejects from a Bradford breaker indicated that this form of preliminary preparation was not suitable for coal from the Wongawilli seam.

5. Microstructure of Brown Coal.

(Pollen Research Unit.)

The work of the Pollen Research Unit at the Botany School, University of Melbourne, has been largely concerned with the pollen and phytoplankton content of Cretaceous and Tertiary salt-water deposits in Victoria, South Australia, Western Australia, New South Wales, and Papua. As a result, twenty fossil pollen types have been described and their distribution has been noted. Furthermore, the first comprehensive account of fossil microplankton, other than foraminifera, from the southern hemisphere is now in course of publication. This includes records of 25 genera, of which four are new, and 75 species, of which 46 are new. The latter work was made possible by the generous collaboration of Professor G. Deflandre of Paris.

These two lines of research have made it possible to establish the occurrence of Eocene and cretaceous sediments in the deeper levels of the Nelson Bore,

Victoria—where they were not previously recognized—and have afforded a means of correlation of these sediments with those of the Pebble Point-Moonlight Head succession.

A study of the pollen grains of living Australasian members of the family Myrtaceae has been completed, and the pollen grains of the New Guinea and New Caledonian species *Nothofagus* have been investigated.

A report on deposits in the Murray River basin is in the hands of the Director, South Australian Department of mines, for subsequent publication.

6. Utilization of Low-rank Coal.

(Division of Industrial Chemistry.)

(*a*) *Pressure Gasification.*—The primary object of this project is the investigation of the chemical reactions by which methane is synthesized when brown coal is subjected to pressure gasification. At present the nature and mechanism of these important gas-enrichment reactions are only imperfectly understood, and it is expected that the results of this research will not only give a more complete knowledge of the theory of the established Lurgi pressure gasification process, but will define the lines along which improved gasification processes could be developed.

The experiments planned have been designed to determine individually the contributions made to methane synthesis by coal hydrogenation, carbon hydrogenation, and hydrogenation of carbon monoxide, either catalysed or uncatalysed, and to study the kinetic features of each set of reactions. The rather complicated reaction equipment and auxiliary plant required for this project have been completed and experimental work has commenced.

(*b*) *Fundamental Studies Related to the Gasification of Coal.*—Fundamental work is in progress on other chemical reactions and the physical properties of brown coal and brown coal chars which are important to coal gasification.

An investigation of the effect of high steam partial pressures (up to 50 atmospheres) on the rate of the steam-carbon reaction is making steady progress. A knowledge of the kinetic features of this reaction at superatmospheric pressures is important to future developments in synthesis gas production as well as to gas production from brown coal. Previous work on this reaction under comparable conditions has been restricted by the difficulties of the experimental techniques required. Results so far obtained show promise that many of these problems have been solved. By careful preparation of the ash-free carbon samples used it has been possible almost completely to eliminate the interference of the secondary water-gas shift reaction, thus isolating the primary steam-carbon reaction for direct study.

In continuing investigations of the physical structure of brown coal and char samples, much of the effort has been directed to the development of a high-pressure mercury penetration apparatus, designed to determine the nature of the micropore structures with effective diameters as small as 40-60 Å. It is suspected that a fairly large proportion of the total internal surface area of char samples determined by nitrogen adsorption is contributed by these micropores. A knowledge of the overall distribution of pore sizes is necessary to enable an estimation to be made of the proportion of internal carbon surface effectively available to gaseous reactants, and thus to assist the interpretation of kinetic reaction data.

The mercury penetration porosimeter initially constructed was designed for a working pressure of 30,000 lb./in.^{2}. It was subsequently found that it was desirable to increase the maximum pressure attainable to 40,000 lb./in.^{2}, which is substantially higher than has been achieved in similar apparatus elsewhere. This involved changes in the means for applying pressure to the system, and the development of a new method of measuring the volume of mercury which penetrates into the sample. These problems have now been solved satisfactorily.

(*c*) *Analytical Investigations.*—The complete analysis of gas samples to a high degree of accuracy consumes a considerable proportion of the time and effort expended on many of the projects concerned with brown coal gasification. It has therefore been necessary to give attention to possible means of improving and increasing the rapidity of established gas analysis methods, and to the examination of new principles in gas analysis. The partial mechanization of the Bone and Wheeler apparatus has eliminated much of the time-consuming drudgery of this method without loss of accuracy. A thorough study of the capabilities of the Gooderham soap-film apparatus has been made, and an improved model of this apparatus using solid absorbents has been constructed. A new method of gas analysis applying the principle of gas chromatography to separate the gas mixture into its constituents, with separate estimation of each fraction by a thermal conductivity detection cell, is now being investigated.

An investigation has been made of the recently developed Spooner method for the direct determination of oxygen in coals. Although originally developed for the analysis of low-oxygen bituminous coals, it has been shown that this method is applicable, within certain limitations, to brown coals containing, on the average, 25 per cent. oxygen. The results of the analysis by this method of brown coals from all the major deposits in Victoria have shown that appreciable errors may be involved in the estimation of oxygen content by difference, the method normally employed.

A study has also been made of the changes which occur in brown coal mineral matter during ashing, with the aim of developing an improved formula for the conversion of ultimate analyses of brown coal samples to the pure coal basis. It is believed that significant advances have been made in this respect. By using statistical methods applied to a large number of recorded total analyses of brown coal samples from all the major and many of the minor fields in Victoria, it has been shown that the pure coal substance in each case is very similar, except in so far as organic sulphur may replace oxygen.

(*d*) *Fluidization Studies.* — In continuance of investigations of possible methods by which the results of fluidization tests carried out with air at atmospheric temperature and pressure as the fluidizing medium may be extrapolated to predict the physical performance of fluidized bed reactors operated under very different conditions, a study has been commenced of the influence of gas viscosity on fluidization characteristics.

Further work has also been done on the development of an instrument for determining fluidization quality in a fluidized bed reactor operated at high temperature.

A theoretical study, supported by considerable experimental work, has been made of the stability and optimum performance of multi-jet gas distributors for fluid bed reactors.

7. Solar Water Heating.

(Central Experimental Workshops.)

Further work has been carried out on the development of flat-plate solar absorbers, and prototypes of a design considered suitable for domestic water-heating applications have been constructed and tested. While most of the test data obtained have related to conditions in Melbourne, one unit has been in service at Merbein for over twelve months, and six others are being installed in various locations between Brisbane and Adelaide where their performance can be recorded.

Equipment is also being supplied for other permanent installations, including one at Katherine in the Northern Territory.

The capital cost of a solar domestic water heater is considerably higher than that of a comparable electrical heater, mainly owing to the expense of the absorber itself. The design of the latter has now been simplified in some respects to facilitate manufacture, and it is possible that further substantial savings can be made in this direction.

XXI. PHYSICAL METALLURGY.

1. General.

A programme of research on specialized projects in the field of metallurgy is undertaken at the Section of Physical Metallurgy established in the Research School of Metallurgy at the University of Melbourne under Professor J. N. Greenwood. This work is described below. Work on metal physics is in progress within the Division of Tribophysics (*see* Chapter XXII.). The work of the Division of Industrial Chemistry on foundry sands is reported in Chapter XVIII., Section 4.

Section of Physical Metallurgy.—The main investigations described in the previous Annual Report have been continued, although some of the work on the oxidation of titanium has been discontinued with the resignation of Dr. A. E. Jenkins, who has taken up a post as Senior Lecturer in Process Metallurgy at the New South Wales University of Technology.

Dr. H. W. Worner has been seconded to the Mines Department of Canada and is working on the metallurgy of titanium.

Members of the Section have assisted in the supervision of post-graduate students, and a number of inquiries on metallurgical problems from industry have been answered.

2. Titanium and its Alloys.

(Section of Physical Metallurgy.)

(*a*) *Alloys.*—The investigation of the strength at high temperatures of titanium alloys has been extended to the study of complex solid solutions in the α-form (e.g., titanium-aluminium-oxygen) and also of the effect of a second phase, such as titanium carbide. The complex alloys show no significant improvement in tensile properties at 600° C. over the best of the simple α-alloys (e.g., titanium-aluminium). Alloys consisting of β-titanium retained by suitable additions have also been tested. It is hoped to correlate these results with those from creep tests now in progress, in which creep is developed by bending.

The behaviour of the titanium alloys at temperatures up to 600° C. suggested that strain ageing was taking place, and this and other effects are being investigated by a study of internal friction of titanium and its alloys.

(*b*) *Reactions with Oxygen.*—The effect of a number of selected alloy additions on the resistance of titanium to oxidation has been studied at temperatures up to 900° C. Up to 850° C. all the alloys showed a marked increase in the rate of oxidation. At 900° C. tungsten and aluminium retarded the oxidation, whereas the other additions (zirconium, iron, and tin—particularly the latter) cause a very marked increase.

The oxide scales formed on the above titanium alloys at temperatures up to 1,000° C. are being analysed to study the diffusion rate in the oxide of the added elements in relation to that of titanium.

3. Deformation.

(Section of Physical Metallurgy.)

The study of the creep of lead and its alloys has been continued. Particular attention has been directed to the recrystallization of pure lead during creep. The influence and interdependence of factors such as impurities, grain size, previous strain, and boundary migration have been studied and more detailed pictures of the mechanisms of recrystallization and creep deformation are being obtained.

Experiments have been made using fractured creep specimens of lead-thallium alloys as the starting material for new creep tests; the mode of deformation of this material reveals an unexpected absence of slip and other changes within grains and may help interpret the mechanism of tertiary creep.

Titanium and some of its alloys have been deformed at constant rates of strain (1 or 10 per cent. per hour) at temperatures up to 700° C. in a vacuum of 10^{-6} mm. Hg. The changes of microstructure have been studied by using X-rays and the optical microscope. There is very little twinning at room temperature, and none at high temperature; slip becomes less evident and changes character, and a substructure appears at high temperatures. In general, titanium shows changes intermediate between aluminium and zinc, as might be expected from the crystal structures. The effects of oxygen have been investigated, with the oxygen as the alloying addition and in surface layers of oxide or alloy.

XXII. TRIBOPHYSICS.

1. General.

The Division of Tribophysics has developed from the former Lubricants and Bearings Section established during the war to assure Australian engineering industry of essential information in the manufacture of bearings for aero and other engines. The original investigations have been continued and extended to include fundamental studies in metal physics, the surface physics and chemistry of solids, and reaction kinetics. Major advances have been made in the knowledge of distortions in metals produced by plastic deformation, of phase changes in metals, and of the mechanism of oxidation reactions.

Division of Tribophysics.—The work of the Division has been continued along the general lines described in the last Annual Report.

As in previous years, the Division has co-operated with the Chemistry, Metallurgy, Mining, Physics, and Engineering Departments of the Melbourne University and is indebted to these Departments for the use of many facilities.

Advice and assistance have been given frequently to numerous industrial firms, government organizations, departments of various universities, and other Divisions of the Organization. The range of subjects —lubrication, bearings and bearing metals, wear, metals technology, electrolytic polishing, electronics, and surface chemistry—illustrates the way in which the fundamental investigations of the Division are related to practical applications. The volume of these inquiries has approximately doubled during the present year.

Officers of the Division have continued to act on various committees, in particular, the C.S.I.R.O.—Department of Supply Engineering Group Committee, and lubrication committees of the Department of Supply. They also took an active part in organizing a symposium on surface chemistry in Melbourne. The metallurgical colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

The Chief was a delegate to the meetings of the International Union of Pure and Applied Physics in London and the International Union of Crystallography in Paris in July, 1954.

2. Properties of Surfaces.

(Division of Tribophysics.)

Apart from investigations on some practical aspects of friction and lubrication, the work on the physics and chemistry of solid surfaces is concerned mainly with the topography of surfaces of metal crystals and with the behaviour of molecules adsorbed on solids.

(*a*) *Bearing Testing.*—The reconstructed apparatus has proved to be satisfactory and experiments have been made on the effect of the surface finish of the journal, the diametrical clearance, and the geometric accuracy of the bearing assembly, on the performance of the bearing during running in and its ultimate performance.

It is found that, provided the whole bearing assembly is manufactured and aligned extremely accurately, bearings of very small clearance run in most rapidly and to a very high ultimate performance. A very smooth journal appears to favour this rapid running in.

(*b*) *Desorption from Solid Surfaces.*—The radioactive tracer technique, which was developed to study surface migration, has been used to investigate the desorption of monomolecular layers of stearic acid and some of its soaps. Autoradiographs show that on unreactive surfaces, such as platinum and quartz glass, the acid is weakly adsorbed and almost complete evaporation readily occurs in air at temperatures just above the melting point of stearic acid. Layers of copper or calcium soaps, either deposited as such or formed *in situ,* are much more stable, and desorb appreciably only at much higher temperatures. Hot benzene removes any physically adsorbed molecules, either acid or soap, but some molecules which are chemically bonded to the surface are able to resist dissolution. There is also evidence that the presence of water vapour assists thermal desorption.

(*c*) *Monomolecular Layers on Water Surfaces.*—Measurements on stearic acid monolayers on very pure water have demonstrated clearly that the generally accepted behaviour of the monolayers on alkaline substrates, previously ascribed to ionization of the carboxyl group of the acid, is in fact caused by a reaction between the monolayers and impurities in the water. On very pure water ionization of stearic acid has no large effect on the molecular packing in the monolayer. The true change in surface potential caused by ionization is about half the accepted value, i.e., the value obtained on solutions containing calcium. Correct values of these fundamentally important quantities have been published.

(*d*) *Catalysis and Topography.*—As stated in last year's Report, the activation energy of the catalytic decomposition of formic acid on silver crystals depends strongly on the orientation of the macroscopically flat surface. Such a surface is probably made up of facets of different atomic arrangement, the type of which changes with the orientation of the specimen and the treatment of the surface.

Measurements have been carried out on crystals which have been polished electrolytically, and for orientations where one type of facet is predominant the activation energies have been found to be similar to those measured on untreated surfaces.

Crystal facets can also be produced by thermal etching, a technique which in itself should not introduce contaminating surface films. As a preliminary to the use of such surfaces for catalytic experiments a study has been made of the facets exposed by different conditions of thermal etching on crystals of different orientations. On silver crystals heated in air to about 900° C. the plane developed by etching is predominantly (111). However, if the specimen surface is within about 15° of the (100) plane then the etched surface is predominantly made up of (100) facets.

The orientations of the crystals are determined from the measurements of the angles between three traces of (111) planes revealed by thermal etching or by twin boundaries. A series of graphs has been constructed to facilitate the determination.

3. Metal Physics.

(Division of Tribophysics.)

The aim of the work is to obtain a better understanding of the plastic properties of metals and of the mechanism of phase changes. This knowledge will make it possible to state the best conditions of a material for use in practice and widen the range of materials available to industry.

(*a*) *Plastic Deformation.*—The strength of metals and alloys depends on the type, number, and distribution of imperfections (dislocations, vacant lattice sites, and interstitial atoms) in the metal crystals. Some of these imperfections are present in the undeformed metal, others are produced during the deformation, and they affect the properties in various ways. Their presence causes a small proportion of the energy expended in deformation to be stored in the metal and this energy is released when the metal is heated. By measuring the amount of energy stored and the manner of its release, and relating such measurements to those of other properties, some details of the various imperfections and the role they play in plastic deformation may be determined.

To this end, measurements are made of the stored energy, using a highly sensitive calorimetric method, of the electrical resistivity, hardness, macroscopic density, and the distribution of intensity in X-ray diffraction patterns from deformed metals. A differental method has been developed to allow the small changes in density of a deformed specimen, at various stages of the annealing process, to be followed. The change in shape of the X-ray diffraction lines is determined by means of a Geiger counter spectrometer. This change in shape is mainly due to internal strains in the crystals and a reduction in the effective crystal size. These two phenomena can be separated by Fourier analysis of the line shape. In the measurement of the integrated intensity of a line, errors arise from the statistical fluctuations in the counts. It has been shown theoretically that, for a given total time of counting, there is an optimum time of counting at each part of the line and also that there is an optimum stopping point in the tails of the line, so that the standard error in the measured integrated intensity is a minimum.

Experiments described in last year's Report have shown that at least three mechanisms may operate in the liberation of stored energy during the heating of a deformed metal. These are the disappearance of vacancies, "recovery" involving the rearrangement and annihilation of dislocations, and recrystallization, which is accompanied by the disappearance of the remaining excess of dislocation due to deformation. The manner in which the energy associated with these three processes varies with the amount of deformation has been studied for nickel, arsenical copper, and pure copper. The rate of release of energy as a function of temperature in the range of recrystallization is being analysed mathematically in order to determine the kinetics of the process by which the energy is released.

(i) *Nickel Deformed in Torsion.*—All three processes are observed. The total stored energy increases linearly with the amount of deformation and a similar type of increase is found in the energy associated with each of the three processes. The slope of the curve is small for the vacancy process, greater for recovery, and greatest for recrystallization.

(ii) *Nickel Deformed in Filing.*—Some energy is released prior to recrystallization in a similar manner to the solid specimens, but proportionally more energy is released by recrystallization. This takes place over a much wider temperature range. The total energy per unit volume is several times that for a solid specimen deformed to fracture.

The X-ray analysis of the line shape indicates that the particle size is small and remains practically unchanged during the release of energy prior to recrystallization. On annealing at higher temperatures the particle size increases and continues to do so even after all the energy has been released.

The internal strains calculated for the filings vary in a similar manner to the stored energy.

(iii) *Arsenical Copper Deformed in Torsion.*—Only two processes, recovery and recrystallization, are observed. The variation in the energy associated with each of these processes with deformation is similar to that obtained for these processes in nickel.

(iv) *Pure Copper Deformed in Torsion and Compression.*—The process of recrystallization is responsible for almost the whole of the release of stored energy. It had previously been shown that the stored energy increased linearly with the amount of deformation in torsion, and the same result has now been obtained for deformation in compression.

(v) *Pure Copper Deformed in Alternating Tension and Compression (Fatigue).*—Recent results of other investigators had suggested that not only was no energy stored during fatigue but that the energy content of a metal after fatigue was even lower than that of the annealed metal, i.e., the fatigued metal absorbed energy on annealing. This was contrary to accepted views on the nature of fatigue. However, our work has shown that a measurable quantity of energy is stored during fatigue, although the manner in which it is released during heating differs from that for other types of deformation.

(*b*) *Phase Changes.*—The hardening of steels and light alloys during heat treatment is due to the occurrence of various types of phase changes; the mechanisms of these phase changes are being studied.

In continuation of the theoretical work undertaken last year, extensive numerical calculations have been made of the predicted habit plane for transformations from the body-centred cubic to the hexagonal close-packed structure, such as occurs in titanium and in certain copper-aluminium alloys. An examination of the experimental results recorded in the literature suggests strongly that this transformation may take place in more than one way (e.g., in certain titanium alloys); the theory should be capable of dealing with this variation.

The theory allows for the possibility that a transformation from, say, the face-centred cubic to the body-centred tetragonal structure, as in the austenite-martensite transformation in iron and its alloys, may have a different geometry (orientation relationship and habit plane) from the transformation in the reverse direction. Overseas experimental work has confirmed the existence of a differing mode of reverse transformation.

An experimental investigation of the precipatation in the super-saturated, α-solid solution of copper-beryllium alloys has now been completed. The application of the general theory to the new data leads to a satisfactory explanation of the observed irrational habit plane and of the orientation relationship. The good agreement between theory and experiment indicates that, at least in the initial "coherent" stage of transformation, the so-called diffusionless (or martensitic) and the diffusion controlled (or nucleation and growth) transformations occur by a similar mechanism.

An essential step in the study of diffusionless transformations is the observation of relief effects on polished surfaces. In certain cases, e.g., with cobalt, it is necessary to observe these effects at elevated temperatures. For this purpose, a novel microscope hot stage has been developed in which electron bombardment is used to heat the specimen. This method of heating has also been used for growing single crystals and for special heat treatments.

4. Reaction Kinetics.

(Division of Tribophysics.)

The reaction kinetics work which is now concluded arose ont of war-time investigations of the detonation of explosives. These revealed that much was still unknown concerning the fundamental chemistry of combustion, and in 1949 a programme of work was begun on the mechanism of slow oxidation of organic compounds. Since oxidation is responsible for the deterioration of lubricating oils and numerous other industrial and agricultural products, for the drying of paints, and for the incidence of "knock" in the internal combustion engine, it is of considerable praetical as well as theoretical importance.

In addition since, in common with other chemical reactions, oxidation follows on interaction between colliding molecules, an investigation of the thermal conductivities of organic compounds in the vapour state was initiated as a means of studying molecular collisions under less extreme conditions. This work was concerned with the variation of the conductivity with pressure and temperature. It was shown that the effect of pressure is proportional to its effect on the specific heat of the vapour. The variation with temperature provided information on the mode of exchange of the rotational and vibrational energies of the molecules with their translational energy during collision. The mutual interaction was found to be strongly influenced by the polarity of the molecules but the factors involved are now well enough understood to explain the behaviour of like and unlike molecules on collision.

Oxidation at ordinary temperatures takes place by a chain reaction leading to the formation of peroxides which subsequently decompose. The mechanism of formation of the peroxides from compounds of a certain type (olefines) is well understood. Investigation showed that the oxidation of aldehydes, compounds which occur as intermediate products of oxidation at higher temperatures, occurs in fundamentally the same way. Certain abnormal featnres which obscure the similarity were traced to the concomitant formation of an inhibitor. The decomposition of the peroxides produces free radicals which initiate further oxidation; but the rate of decomposition of a peroxide in isolation is not a measure of the initiation rate in an oxidation system, for in isolation the decomposition itself becomes a chain reaction. However, it was shown that this can be suppressed to the primary rate of radical production by the addition of an inhibitor (anti-oxidant) of the appropriate type. When phenols (a common type of anti-oxidant) are used, however, the limiting rate is not observed because of a hitherto unsuspected direct interaction between the phenol and the peroxide.

In gaseous oxidations at higher temperatures the mechanism becomes more complicated. Analytical and kinetic investigations with selected hydrocarbons showed that the reaction takes place in two successive stages, a different mechanism operating in each. In the first stage the development of the reaction is controlled by the accumulation of active intermediates in the gas phase, and by processes occurring at the walls of the reaction vessel. The active intermediates may be accelerators (e.g., higher aldehydes) or

inhibitors (e.g. formaldehyde), some variation occurring from one compound to another. In the second stage, reactions in the gas phase predominate. The initial condition of the surface of the vessel is thought to influence the reaction through its effect on the production of inhibitors and the consumption of reagents during the first stage; changes in the surface brought about during the reactions have little effect on its subsequent course. Contrary to a widely held view, the development of the reaction in the cases studied does not depend upon the accumulation of peroxides, and it seems probable that this is true of the oxidation of gaseous hydrocarbons in general.

XXIII. NATIONAL STANDARDS LABORATORY.

The statutory functions under the *Weights and Measures (National Standards) Act* 1948 of maintaining the Commonwealth standards of measurement are carried out at the National Standards Laboratory by the Divisions of Metrology, Physics, and Electrotechnology.

The work of the Laboratory in regard to standards is closely related to that of other national standards laboratories and to that of the International Bureau of Weights and Measures.

At the Tenth General Conference of the International Committee of Weights and Measures, held in Paris in October, 1954, important resolutions were passed concerning the basic standards of measurement. Mr. N. A. Esserman, Chief of the Division of Metrology, attended this meeting as Australian Delegate. Sixty-five countries were represented at this Conference, which meets at intervals of about six years. Mr. Esserman was elected a member of the International Committee of Weights and Measures.

The question of replacing the arbitrary international metre by the wavelength of the light emitted by some suitable isotope has been under consideration for a long time. The Tenth General Conference requested standards laboratories to pursue as actively as possible their studies of monochromatic radiation so that a definite decision on this question may be made at the next conference.

The thermodynamic scale of temperature was redefined at the Conference in terms of the temperature of the triple point of water, a temperature close to that of the melting point of ice but one which can be measured with considerably more certainty. The Conference defined the temperature of the triple point of water as 273.16° K. This means in effect that the thermodynamic temperature scale is defined by the temperature of a single fixed point instead of by the temperature interval between the melting point of ice and the boiling point of water.

The International Committee of Weights and Measures is concerned only with the metric system. The problem of achieving uniformity in the definition of the basic units of the imperial system of weights and measures, which is in general use in the British Commonwealth and the United States of America, has for long been under discussion. Considerable progress in regard to agreement as to basic definitions of the pound and the yard was made at a conference between representatives of the United Kingdom and the United States of America at Washington in November, 1954. The Chief of the Division of Metrology, Mr. Esserman, was present at these discussions as an observer.

Scientific and industrial research is continually requiring greater precision in the measurement of physical quantities. The maintenance of standards is, therefore, a continually expanding function calling for research and for precision equipment. All the Divisions of the National Standards Laboratory are experiencing the need for additional laboratory space for these purposes.

Details of the test and calibration facilities of the Laboratory have been described in a series of six pamphlets dealing with the following fields:—1. Heat, hygrometry, and viscometry; 2. Optics and photometry; 3. Electricity and magnetism; 4. Engineering metrology; 5. Materials testing machines and mechanical instruments; 6. Physical instruments.

Details of the work of the Divisions of Metrology, Physics, and Electrotechnology are given in Chapters XXIV., XXV., and XXVI. respectively.

XXIV. METROLOGY.

1. General.

Among the basic factors in modern engineering production are uniformity of quality and performance. Industry therefore requires to be able to make accurate measurements. Equipment used for this purpose must be regularly controlled, checked, and calibrated against appropriate working standards. These in turn require periodical calibration in terms of the national standards, certain of which are maintained by the Division of Metrology.

Division of Metrology.—The Division is responsible for the Commonwealth Standards of measurement of length, mass, time interval, and associated physical quantities.

The main effort of the Division is directed to the statutory and industrial requirements in respect to national standards, but the Division also actively engages in research on precision measurements and applied mechanics.

A Metrology Exhibition was held at the Division in August, 1954. The exhibition was part of the Division's policy of bringing the latest scientific and technical developments to the attention of industrial and other people. On-the-spot advice was given and the exhibition also served to show the facilities available to the industry. On behalf of the Standards Association of Australia, an officer of the Division represented Australia at the American, British, and Canadian Conference on the Unification of Engineering Standards, held in New York.

During the year the Chief of the Division made a visit overseas to attend conferences dealing with national standards and also to investigate recent research trends at overseas Standards Laboratories. During this visit he attended the Tenth General Conference of the Bureau International des Poids et Mesures in Paris, and also the meeting of the Provisional International Organization for Legal Metrology.

During the year lectures have been given to technical and scientific institutions.

Mr. N. J. C. Peres was appointed Technical Secretary of the Division in December, 1954.

2. Length and Associated Quantities.

(Division of Metrology.)

(a) Standards.—At the Tenth General Conference of the Bureau International des Poids et Mesures it was agreed that the definition of the metre should not be changed yet, but that research should continue on isotopic light sources, so that a definite proposal for the adoption of the wavelength of light as the ultimate unit of length can be made at the next conference. This means that the production and study of light sources, the precision measurement of wavelengths and their line widths, and the establishment of line and end standards by direct interferometry are projects of increasing importance in the Division.

During the year, considerable progress has been made in determining all the Division's end standards up to and including 12 inches in length, by interferometry in terms of wavelength standards of isotopic sources. Where previous interferometric determinations carried

out by the National Physical Laboratory, England, were available, agreements of the order of one part in five million were obtained. End bars have also been calibrated for the Department of Supply.

(i) *Maintenance.*—The regular programme for the maintenance of the line and end standards of length held by the Division has continued. Lapping investigations into the fine surfaces required for end standards, slip gauges, and platens have continued. An electromagnetic comparator, magnification × 30,000, has been equipped for the calibration of sets of slip gauges.

(ii) *International Calibration.*—Remeasurement was carried out on four end standards 25, 50, 75 and 100 millimetres in length, returned from France after measurement at the B.I.P.M. in Paris. The measurements made in Paris agreed again with those made in the Division to 0.01 micron, or half a millionth of an inch.

(iii) *Universal Line Standard Comparator.*—This was used in the calibration of scales and the determination of the thermal coefficient of linear expansion of various scales and sample lengths of invar tapes. Modifications to the comparator have reduced vibration effects to negligible amounts.

(iv) *Geodetic Base.*—Work continued on the calibration of the geodetic base, and the full 50-m. interval was used to determine three 50-m. invar tapes. The accuracy of determination of these tapes was 3 parts in 10^6.

(v) *Kösters-N.S.L. Interferometer and Isotopic Light Sources.*—A study of cadmium, krypton, krypton 86 isotope, and mercury isotope lamps has been completed with the Kösters-N.S.L. interferometer. End standards were measured up to 500 mm. in length, and the performance of the interferometer was fully tested for measurements in air and *in vacuo* with continuous control of temperature to within 0.005° C.

(vi) *Wavelength Data and Correction Tables for Length Interferometry.*—These tables mentioned in last year's Report have been modified slightly on the suggestion of overseas laboratories, so that the data are calculated in terms of the standard water vapour pressure of 10 mm. of mercury.

(vii) *One-metre Interferometer.*—This is now under construction. Tests with Fabry-Pérot fringes in reflection at a path difference of 400 mm., using high-frequency electrodeless mercury 198 lamps, have been completed.

(viii) *Multiple-beam Interference Comparator.*—This comparator, which will be used in the calibration of end standards, is now being assembled.

(*b*) *Interferometry Investigations.* — Thin-film studies and investigations into surface finish and structure and into other problems related to metrology have continued, using interferometric techniques.

(i) *Liquid Surface Interferometry.*—Further experimental work has been done on mercury surfaces, using special anti-vibration mountings. Using a metallized optical flat over a mercury surface, it is possible to observe sharp multiple-beam fringes, the amplitude of vibration of which is a precise, relative measure of the vibration characteristics of the surface on which the mercury pool is mounted. A method of measuring the surface tension of liquids by interferometry has been developed.

(ii) *Multiple-beam Interferometry.*—Various surfaces have been examined by the multiple-beam interference microscope for surface quality and structure. An investigation has been completed on the measurement of small vibratory displacements by examination of the intensity pattern of overlapping multiple-beam fringes. It is possible to measure displacements of the order of six fringes (0.00006 inch) without the use of stroboscopic techniques. Such a method can be applied, for example, to the study of oscillating crystals.

(iii) *Effects of Collimation and Oblique Incidence in Length Interferometers.*—A general analysis of the effect of oblique rays involved in the use of length interferometers of different types reveals that the widely accepted correction relationships are not valid in the general sense. Precise correction curves for these effects have been prepared for different forms of diaphragm apertures used in interferometers.

(iv) *Adhesive Contact between Flat Surfaces.*—The thin liquid film required to induce a strong adhesive contact between highly finished flat surfaces does not separate the surface effectively. There is a small contact between solid surfaces, and the degree of this contact influences the effects on length measurement. There is evidence that the contact error may be positive or negative but is not greater than 0.01 micron in magnitude if the adhesive contact is good. If measurements are required to a greater accuracy than this it is desirable to avoid the use of adhesive contact.

(v) *Deposition and Measurement of Thin Films.*—A wide variety of metal and dielectric films have been deposited by evaporation and sputtering methods for research projects in the Division and for other Divisions and Universities. Further experiments have been done in preparing graticules by the double evaporation of aluminium and chromium. A photoelectric transmission comparator has been completed for the measurement of the optical characteristics of thin films.

(vi) *Phase Loss Studies.*—Experimental work is in progress on the evaluation of phase loss at reflection as a correction factor in length measurement by interferometry.

(vii) *Interference Microscopy.*—The multiple-beam interference microscope has been used in many problems associated with surface fracture and thin film thickness, and a two-beam interference microscope having a maximum magnification of x760 has been acquired for the study of surface finish.

An interference microscope incorporating both a Michelson two-beam system and a Fizeau multiple-beam system and using stock microscope parts has been designed in the Division.

(*c*) *Engineering Metrology.* — (i) *Measuring and Consultative Service.*—A particular item of interest was the determination of the alignments of two large steel strip rolling mills, one hot and one cold, the accuracies of measurement attained being 10 seconds of arc over 100 feet and 4 seconds of arc over 40 feet respectively.

Assistance was given in the measurement of noise in machinery and measurements of displacement on a model of the Warragamba dam have been carried out.

Items of equipment for test included sets of slip gauges, length bars, production and inspection gauges of all types, invar surveying staves and tapes, lathes, optical flats, tools, and measuring instruments.

(ii) *Periodic Errors in Machine Tools.*—Progress has been made in the development of electronic equipment for the measurement of periodic errors in machine tools. Experimental equipment has been set up using electrical signals to simulate the machine under test.

(iii) *Gears and Gear Hobbing Equipment.*—A large gear wheel hobbing machine and double helical test gear were examined on behalf of the Department of Defence Production. A number of marine turbine gears were examined on behalf of the Department of the Navy and a variety of gears and gear cutting equipment examined for industrial firms. A new design of a portable transverse pitch measuring instrument for large gears has been made.

(iv) *Dividing Engines.*—Numerous and varied linear and circular scales and optical graticules have been ruled on the engines, for experimental projects.

(v) *Photogrammetry (Aerial Surveying).* — A general analysis of the problem of asymmetric distortion in aerial cameras has been made and graphical, analytical, and tabular methods of treating results have been evolved to obtain distortion curves which are symmetrical at a specified angular zone even if the lens contains de-centred elements.

3. Mass and Associated Quantities.

(Division of Metrology.)

(*a*) *Standards of Mass.*—Mass standards of nominal value not greater than one kilogram have been made from austenitic stainless steel. Some weights of nominal value greater than one kilogram have been made from aluminium bronze. This material was chosen as an economic alternative to stainless steel for large weights, since it has good corrosion resistance and anti-magnetic properties.

A full intercomparison of the reference and working standards of mass held by the Division was not made during the year, but those comparisons which have been completed indicate that no significant changes have occurred in any of the important standards.

(*b*) *Density Measurement.*—An additional pair of standard plummets has been constructed for use in liquids of high density and a vessel of novel design has been made, incorporating its own circulating system which permits the use of the minimum volume of liquid in density and volume measurements. Further measurements have been made on the changes in density which occur when strained metal specimens are annealed at progressively increasing temperatures.

(*c*) *Barometry and Pressure Measurements.*—Equipment for the calibration of barometers over a wide range of pressures, 500 to 800 millimetres of mercury, has been constructed and put into operation. An electronic pressure controller is now being developed which is to control the pressure in the vessel to 0.01 mm. and to extend the range down to 400 mm. The vessel is designed to hold a standard barometer and the instrument under test. Illumination is provided by a single 40-watt, 36-in. fluorescent tube supported vertically at the rear of the vessel which illuminates two diffusing screens mounted one behind each instrument in the vessel.

Each barometer can be set and read from outside the vessel.

Equipment has been set up for the production of mercury of very high purity. The equipment comprises units for the removal of base metals, volatile material, and grease, and also a vacuum distillation unit for the removal of noble metals.

4. Time Intervals.

(Division of Metrology.)

A novel method has been developed for measuring and analysing the geometric errors of a watch. The watch is mounted concentric with a disk which rotates at the same speed as the sweep hand of the watch, which is directly beneath a slit in the disk. The watch dial is photographed through the slit, the duration of the exposure being equal to the period of rotation of the hand, and a record is obtained of the stationary position of the hand corresponding to each graduation, thereby enabling the error in reading at each graduation to be determined, and from the pattern of the errors it is frequently possible to specify their source.

5. Applied Mechanics.

(Division of Metrology.)

Information has been given to the engineering industry in a wide range of problems relating to measurement of force, pressure torque, hardness, strain, vibration, friction, and angular speed, and to design, balancing, limits and fits, machining and surface finish, tolerances, and drawing practice.

(*a*) *Machining Research.*—Investigations have continued into the Schlesinger Index for machinability. A new abrasion tester has been developed to replace the original, the performance of which was unsatisfactory because of excessive vibration in operation, and a new two-component force dynamometer, incorporating strain gauges as measuring elements, has been designed with sufficient range to cover the materials to be investigated.

Methods for measuring the sharpness of cutting tools have been further investigated.

Comparative tests between the performance of a patented circle-finish method of surface finishing and the well-known process of superfinishing have now been completed.

The Division has received a number of requests for assistance in machining problems. Following upon one such request from a manufacturer, an investigation was conducted into the high-speed routing of aluminium alloys, which was being performed with single-fluted, carbide-tipped cutters at a cutting speed of approximately 3,000 feet per minute. The performance of the cutters was erratic; they often broke down rapidly on the cutting edge, failed by fatigue in the shank, or left a poor finish on the work. The Division investigated the effect of varying the number of flutes, the tool geometry, the tool material, and other factors in the cutting operation. Throughout this investigation, a number of tool manufacturers co-operated readily and generously supplied cutters and tool bits to the Division's requirements. Finally a cutter was designed which cut consistently well, gave much increased tool life and produced a good finish on the work. Full performance tests are now being conducted.

The high-speed finishing of the commutators of aircraft generators, which is normally done by diamond turning, was also investigated at the request of industry. A good finish on these commutators is essential to efficient operation of the generators at high altitude. Experiments, which also involve using the superfinishing head designed in the Division, are being conducted to determine the optimum technique for obtaining the required finish. A completely universal superfinishing and lapping machine acquired for finishing single-point cutting tools was extremely useful in this investigation.

(*b*) *Engineering Design Analysis.* — The special course of lectures for Sydney firms in the telecommunications industry was completed during the year. These lectures illustrated the application in the factory of new methods of analysing the functioning, production, and inspection requirements of engineering designs, and demonstrated the recently standardized vocabulary for specifying such requirements.

Two lectures were also contributed to a series of six lectures on "Engineering Drawings and Dimensions" organized by the Engineering Faculty of the University of Queensland to assist the engineering industry in Queensland.

Further work was done in developing techniques for determining the natural tolerances for machine tool operations and production processes, with the co-operation of an industrial firm.

(*c*) *Vibration.*—(i) *Vibration Isolation.*—Demands from industry for advice and assistance in the solution of vibration isolation problems have been heavy. Three major firms have undertaken the design and construction of special vibration isolating foundations for large and costly precision machine tools, accepting as their basis design principles proposed by the Division. Many others have been assisted in the isolation of smaller plant and instruments.

Within the laboratory, two forms of general-purpose mountings for instruments are being developed, and mountings have been designed and made for certain small compressors, which had been disturbing sensitive apparatus.

Concurrently with this activity, the practical application of the theory to the mounting of particular equipment is being studied further, and the available information and experience collated for publication. There has been serious delay in publishing the first comprehensive survey of the information and to meet immediate requirements abridged papers have been published locally and distributed.

(ii) *Vibration Measurement.* — Unusually heavy demands for measurement services has retarded the further development of vibration measuring techniques and instruments. Electronic capacitytype transducers in prototype experimental form have been used to meet immediate needs. Visits have been made to various factories and vibration measurement made, in most cases to assess the suitability of sites proposed for the installation of sensitive equipment, but also for other special purposes, including the investigation of lathe vibration and the disturbance of a residential building by nearby large compressors. A paper is being prepared on the measurement and isolation of vibration with emphasis on the work of the Division in these fields.

Design of a three-component transducer to facilitate measurement of structural vibration investigations has been commenced and a proposed vertical suspension tried in prototype form. A simple pendulum suspension for an optical vibrometer is also being tried. Equipment has been received for incorporation into a vibrometer calibrator, but immediate needs have still been met by improvised set-ups.

(*d*) *Dynamic Balancing.*—Examination of machines for the dynamic balancing of rotating components for heavy machinery has continued. A simplified balancing techniqne, developed by the Division, is being adopted in industry. Numerous inquiries were received about the theory and techniques of balancing, and collation of the available information has commenced. An Australia-wide survey was undertaken to determine dynamic balancing equipment and services available to inquirers for the routine balancing of components like flywheels and armatures.

(*e*) *Measurement of Physical Quantities.*—(i) *Force.*—Additional proving equipment is being obtained to extend the range of force measurement to meet demands from industry. Two proving rings, each of 300,000 lb. capacity, have already been acquired and this proving equipment will be in continual use for the verification of materials testing machines.

(ii) *Hardness.* — A new Brinell hardness testing machine has been acquired for the calibration of hardness test blocks and for certain hardness projects.

Investigations have been carried out on the dead load Rockwell hardness testing machine made at the Laboratory to N.P.L. design. The behaviour of this machine has been studied, and tests made as part of a programme of intercomparison of Rockwell hardness standards with overseas authorities.

In the measurement of Brinell impressions employing a microscope provided with vertical illumination, the image of the impression is presented as dark on a bright field. In certain cases, using a low-power objective, a peripheral shadow is cast by the distorted metal. The edge of this shadow may readily be mistaken for the edge of the impression, resulting in large errors. An oblique illuminator has been developed which facilitates the measurement and gives greater accuracy. A paper describing the illuminator is about to be published.

(iii) *Spanner Torque and Bolt Tension.*—A survey of available literature on this subject has been completed and a paper published on the prediction of bolt tension. A torque wrench has been made and a preliminary design developed for a torsion cell, for experimental work.

XXV. PHYSICS.

1. General.

Physics, owing to its fundamental character, plays an important role in the development of other branches of science and in technological applications of scientific knowledge. Many Divisions of the Organization are therefore engaged in some branch of physical research. The present chapter describes the work of the Division of Physics, which is one of the Divisions of the National Standards Laboratory. It is responsible for maintaining the Commonwealth standards of heat, light, viscosity, and related fields; calibrating measuring equipment; carrying on physical research; and advising industrial organizations and scientific laboratories generally on precision measurements and allied matters.

Section 5 of this chapter describes the work of the Central Experimental Workshops on precision humidity control and recording equipment for the controlled-climate rooms at Prospect, New South Wales.

Division of Physics.—Very encouraging progress has been made in the development of the new method for measnring humidity reported last year.

An unusual application of the techniques of heat transfer and temperature measurement and control has arisen in the co-operation of the Division with members of the medical profession in order to devise equipment for lowering the temperature of patients to facilitate difficult surgical operations.

The Division's work in solar physics is described in Chapter XXIX., Section 2.

2. Heat.

(Division of Physics.)

(*a*) *Measurement and Control of Temperature.*—(i) *Standards of Temperature.* — The following improvements have been made in the standards of measurement of temperature on the International Temperature Scale:—(1) A new steam-point apparatus has been assembled which gives temperatures reproducible to 0.0002° C. (2) Tests on cells for the realization of the triple point of water over a period of two years have confirmed that they produce a temperature which is stable and reproducible to 0.0001° C. (3) A manometer for the more accurate control and measurement of pressures for the realization of the boiling points of water and sulphur has been designed and its construction is in progress. (4) A new antimony freezing-point eell for transfer from the resistance thermometry to the thermocouple pyrometry range of the Scale has been designed. (5) One of the greatest limitations to accurate temperature measurement in the optical pyrometry range lies in the uncertainty of the colour sensitivity of the observer. Equipment has been set up for the direct measurement of the significant portion of the visual sensitivity curves of the observers and as an alternative approach to the problem a purely physical method of making the observations, which would replace the human eye, is being examined. (6) A nomograph has been developed for use in optical pyrometry which relates black body temperature to apparent brightness temperature for any value of emissivity or transmission. (7) A systematic investigation of the long-term and transient changes which occur in the bulb volume of liquid-in-glass thermometers has been commenced.

(ii) *Temperatures below the Boiling Point of Oxygen.*—Considerable progress has been made in the establishment of standards of temperature at low temperatures.

(iii) *Melting Points.*—Arising from an inquiry concerning the manufacture of an important pharmaceutical product which is subject to decomposition at its melting point, a detailed investigation has been made of the influence of various factors such as rate of heating, size of specimen, and dimensions of container on the apparent melting point of this substance.

(iv) *Hypothermia.*—In co-operation with medical officers of two of Sydney's large hospitals equipment has been designed for use on animal and human subjects to induce, control, and effect recovery from the hypothermic state. The techniques developed have been incorporated in the design of equipment suitable for routine hospital use, and a prototype unit is at present being constructed by a manufacturer of scientific equipment. A direct-reading, rectal resistance thermometer suitable for this type of work has also been developed.

(*b*) *Hygrometry.*—Work has been done on the development of special ionic crystal or electrolytic condensation hygrometers and those to which particular attention has been given are: (1) A relatively simple form of instrument suitable for automatically measuring the dew-point temperature with an absolute accuracy of better than 0.1° C. and a response time of about one second. (2) A self-balancing instrument of sensitivity equivalent to 0.01° C. in dew-point and response time of only 0.3 second. (3) An instrument for use in the accurate regulation of the humidity in air-conditioned rooms. This is being developed with the co-operation of the Central Experimental Workshops for the new laboratories of the Division of Animal Health and Production at Prospect, New South Wales (*see* Chapter VII., Section 22 and Section 5 of this Chapter).

(*c*) *Viscometry.*—The industrial requirement in viscometric measurement necessitates the setting up of a system of standards which will be free from the fundamental weaknesses of the conventional standards and will give greater precision. An accuracy of a few parts in ten thousand relative to the viscosity of pure water at 20° C. as standard is aimed at and the methods under development have a number of novel features.

In the development of this project subsidiary experiments have been completed which have yielded information of wider application than their immediate purpose. The surface tension of dibutyl phthalate has been measured over a wide range of temperatures and the effect of possible surface contaminants examined. Of a number of substances, silicone grease was the only one which was found to spread on this liquid. It has been found theoretically and confirmed by experiment that the surface tension forces on two similar solid objects similarly immersed in and wet by a liquid cannot differ no matter how the liquid surface or any part of it may be contaminated.

(*d*) *Low-temperature Physics, Theoretical Research.*—(i) *Conduction Phenomena in Solids.*—Thermal conduction in solids is due to the transport of energy by the vibrations of the crystal lattice, and in the case of electrical conductors, also by electrons. The investigation of this and related phenomena such as electrical conduction and thermoelectricity, particularly at very low temperatures, provides a powerful tool for the study of the structure of solids. From the theoretical aspect the main concern has been to determine the effect of scattering mechanisms on these transport phenomena, and to use these theoretical conclusions to deduce, from the experimental results on particular materials, details of their crystalline and electronic structures. The principal investigations have been the following:—(1) Quantum-mechanical calculations have been made of the scattering of lattice waves by various model imperfections of the crystal lattice. (2) The effect of conduction electrons and dislocations and other imperfections on the crystal lattice component of the thermal conductivity of metal and alloys has been deduced. (3) The effect of the heat current carried by the lattice on the electronic thermal conductivity of metals and alloys has been shown to be unimportant. (4) The dependence has been derived of the thermal conductivity of non-metals on thermal expansion, elastic properties, and lattice imperfections. (5) A theoretical explanation has been given for the low-temperature conduction properties of some transition metals. (6) The theory of the thermoelectric properties of metals and alloys has been extended.

(ii) *Superfluidity of Liquid Helium.*—It has been known for some time that a gas of particles to which Bose-Einstein statistics are applicable provides a theoretical model which reproduces to some extent the thermodynamic properties of superfluid helium. This theoretical model has now been extended to non-equilibrium situations, and it has been shown that it reproduces many of the superfluid properties of liquid helium.

The phenomenological two-fluid theory of liquid helium, which is used to classify information on superfluidity, has been extended to reconcile the large discrepancy between the predicted and the observed heat flow in narrow slits and capillaries.

(*e*) *Low-temperature Physics, Experimental Research.* — (i) *Low-temperature Facilities.* — The helium liquefier has functioned very satisfactorily and during the past year has produced over 300 litres of liquid helium. Liquid helium is now continuously stored in a vessel from which the evaporation rate is very low, and this greatly facilitates experimental work.

A 15,000 gauss magnet is being constructed for use in the production of temperatures below 1° K. by the process of adiabatic demagnetization, and for experimental measurements in the presence of magnetic fields.

(ii) *Thermal and Electrical Conductivities.*—An investigation of the thermal conductivities due to conduction by the crystal lattice and by electrons and of the electrical conductivities of a series of binary alloys of silver with palladium and cadmium has been completed. This indicates that at low temperatures in annealed alloys the lattice vibrations are scattered predominantly by free electrons, the electrons interacting with vibrations of all polarizations. In alloys of high palladium content the unfilled holes in the d-band are a further source of scattering and in strained alloys dislocations play a major role in scattering the lattice waves.

The thermal and electrical conductivities of pure palladium, iron, and nickel have been measured. In these elements that part of the thermal resistance which is due to the scattering of the free electrons by lattice waves increases as the square of the absolute temperature, as it also does for monovalent metals, but the corresponding electrical resistance has a cubic dependence on temperature rather than the fifth power law shown by monovalent metals.

Facilities for the measurement of conductivities have been improved by the construction of a photoelectric galvanometer-amplifier which enables thermal and electrical conductivities to be measured simultaneously on the same rod-shaped specimen.

(iii) *Specific Heat.*—The construction of a cryostat for specific heat measurements in the range 1.5 to 10° K. has been almost completed.

Improvements have been incorporated in the calorimetric cryostat intended for the measurement of specific heats at higher temperatures (10 to 300° K.) by the addition of a heat exchanger which permits effective use to be made of liquid helium as the

refrigerant for calorimeter temperatures as high as 60° K., thus avoiding the dangers inherent in the use of liquid hydrogen.

(iv) *Temperature Measurement.*—Some calibrations of temperature measuring equipment have been made at the boiling points of liquid oxygen (90° K.) and liquid hydrogen (20° K.) and at intermediate temperatures in the equipment set up for the realization of a temperature scale in this region.

3. Light.

(Division of Physics.)

(*a*) *Photometry.*—(i) *Photometric Standards.*—The extension of the range of photometric standards to include discharge and fluorescent lamps involves two difficulties: heterochromatic photometry and the operation of the lamps under reproducible conditions.

The first is usually met in part by the use of a detector whose spectral sensitivity is corrected as nearly as practicable to the standard luminosity function, though residual errors and slight spectral selectivity of the paint on the integrating sphere lead to appreciable errors in comparing these lamps with incandescent standards. Appropriate corrections may be made if the spectral energy distribution of the sources is known. To this end, an attachment recording spectral energy has been developed for the Laboratory's Hardy spectrophotometer, and is now in use for routine measurements to a precision generally of two per cent.

Discharge lamp characteristics are affected by temperature, so that temperature control of the surrounding air is usually required for reproducibility. This is insufficient, however, for lamp temperature is also affected in a variable manner by air convention. These difficulties have been overcome by using the lamp's current-voltage relationship to indicate the mercury vapour pressure and hence the temperature within the lamp. Calibration at several resistances enables the lamp to be used as a substandard without temperature control, and this technique is being used in building up substandards of luminous flux.

(ii) *Test Work.*—To improve the facilities for photometric work a second photometric bench is being installed as well as a large double monochromator incorporating 6-in. prisms.

The maintenance of standards of haemoglobin concentration and the calibration of haemoglobinometers has been continued. The New South Wales Red Cross Blood Transfusion Service has taken over and extended the regular issue on request, on a Commonwealth-wide basis, of blood samples calibrated on the N.S.L. standard, and the corresponding service formerly provided by the Laboratory has therefore been terminated.

(iii) *Assistance to Industry.*—Besides providing a service for technical information and guidance to industry, in which over a thousand inquiries are received per year, efforts are made to induce manufacturers to use physical rather than subjective methods of measurement and control. In the plastics and ceramics industries there is increasing interest in such methods for the control of colour, a subject which has also been discussed in detail with paint manufacturers.

Other investigations for industry have included the development of a photoelectric control unit for detecting water in oil by the presence of forwardly scattered light, and the examination of methods for measuring the spectral energy distribution of television screens.

(iv) *Optical Properties of Diffusing Media.*—Most common materials, such as paints, textiles, paper, building materials, and soils, may be regarded as optically diffusing media whose colour depends on the spectral reflectance. Studies have been made of the relation between reflectance and the absorbing and scattering properties of the particles and on the refractive index of the matrix in which they are suspended.

The results have applications not only in the precise prediction of colour but also in the chemical analysis of diffusing media by reflection spectrophotometry, for the reflectance is a function of the ratio of the absorption to the scattering coefficients, and hence of the relative concentrations of absorbing and scattering substances. The technique has been applied in the visible spectrum to biological material and plans have been made to investigate the possible extension of this method to the infra-red, where the reflection spectrum of benzoic acid has been successfully obtained with an improvised apparatus.

The diffusion of light from point and line sources has also been studied theoretically and applied to the study of the resolving power of photographic emulsions and its variation with object contrast as limited by diffusion of light within the emulsion. The localizaton of the just-resolved image near the surface has been shown to be due to the relatively low intensity of diffused light at the surface as compared with that at greater depths.

(*b*) *Optics.*—(i) *Reflecting Microscope Objectives.* The design of four-mirror reflecting microscope objectives has been further studied; work is also in progress to improve the performance of the concentric type of two-mirror objective by aspherizing by evaporation. The extent to which this technique can be used in four-mirror objectives is being examined.

(ii) *Image Definition.*—The measurement of optical definition, hitherto a largely subjective matter, can be made by a purely physical method in which the contrast in the image of a specially designed test grating is measured. Equipment for doing this is in an advanced state of construction. To relate the measurements to the optical design of the system, it is necessary to know the image contrast in the presence of various aberrations, a matter already studied in detail in the laboratory for small aberrations. Results have now been computed for larger amounts of defocusing.

(iii) *Optical Facilities.*—The facilities for optical work have been extended during the year by the receipt and installation of a Wild spectrometer which will make possible more precise refractometry and goniometry.

A wave-front shearing interferometer constructed in the laboratory has extended facilities for the testing of large objectives, and progress has been made with the construction and installation of a new universal optical bench.

4. Nuclear Standards.

(Division of Physics.)

Advantage is being taken of the facilities for precision measurements of the Laboratory to redetermine certain nuclear standards. These are (*a*) the energies of alpha particles from certain natural radioactive substances, and (*b*) the gyromagnetic ratio of the proton.

The former are of importance in providing energy standards for nuclear reactors, and the second provides a standard for the precise measurement of magnetic fields. The experimental techniques have applications to the maintenance of the fundamental electrical standards. Considerable progress has been made in the development of the necessary nuclear resonance techniques.

5. Precision Humidity Control and Recording.

(Central Experimental Workshops.)

In the science of hygrometry much effort has been expended in devising equipment to provide an accurate measurement of the relative humidity of air, but considerably less work has been done in the field of humidity controllers. Control sensing elements commercially available are largely of the hair type, which has no pretensions to extreme accuracy or sensitivity: better-quality equipment, such as that incorporating

a lithium chloride cell, can cope successfully with only a small range of relative humidity or has other disadvantages such as slow response to variations.

The accurate control of relative humidity involves firstly, the highly accurate control of temperature, and secondly, the rapid detection and correction of variations in humidity. The sensing element employed must be capable of passing appropriate impulses to a proportional control system with a minimum of delay, and the system as a whole must be stable so that disturbances can be quickly damped out. Although the principle of proportional control has been widely used, its success has always been prejudiced by the limitations of the sensing elements commonly employed.

Extensive investigations have been carried out at Central Experimental Workshops into this problem of obtaining improved equipment for the measurement, recording, and control of relative humidity. With the development by the Division of Physics of the electrolytic condensation hygrometer it was considered that a basis had been established from which sensitive, accurate, and wide-range control equipment could be produced, and present developments are very encouraging. Work on the problem has been carried out in close collaboration with the Division, and prototype sensing elements which can operate controllers or recorders will be available for testing and probable use in the controlled-climate room equipment now being installed at the Sheep Biology Laboratory, Prospect, New South Wales.

XXVI. ELECTROTECHNOLOGY.

1. General.

Much electrical work, particularly in electronics, is undertaken in Divisions and Sections as an integral part of research in other fields of investigation, but the Organization's research on electrical measurements and standards and on electrotechnology is carried out within the Division of Electrotechnology, which is part of the National Standard Laboratory (*see* Chapter XXIII.).

The Organization also collaborates with the Electricity Supply Association of Australia in encouraging electrical research within the Universities through its Electrical Research Board (*see* Section 8 of this Chapter).

Division of Electrotechnology.—The Division is responsible for the maintenance of the Commonwealth standards of measurement of electrical quantities. It also maintains the Commonwealth standard of measurement of frequency in conjunction with the Commonwealth Observatory, Mount Stromlo, and other standards derived from frequency, resistance, and electromotive force. The Division undertakes electrical and magnetic measurements on materials, and the calibration of instruments and equipment such as resistors, bridges, potentiometers, capacitors, inductors, indicating instruments, instrument transformers, signal generators, wavemeters, and fluxmeters. Research is being continued to improve and extend the electrical measuring and standards facilities, and on the dielectric properties of insulating materials and the microwave spectra of gases.

The work of the Division has become much better known in industry and the number of requests for technical advice and assistance has grown rapidly. The demand for calibrations and measurements has also increased, particularly at direct current and at power frequencies.

As in past years officers of the Division have taken part in the work of the Standards Association of Australia and the National Association of Testing Authorities.

The Division was invited by the National Physical Laboratory to participate in an international symposium in electrical standards and measurements. Three papers from the Division were presented by an officer visiting England at the time.

2. Direct Current.

(Division of Electrotechnology.)

(*a*) *Conductivity of Metals.*—More extensive facilities for measuring the conductivity of metals have been installed and provision has been made for precise temperature control of the specimen by means of an oil bath.

(*b*) *Stable Resistors.*—During the previous year some 1,000- and 10,000-ohm standard resistors of an improved design were constructed. The resistors, which are similar to those originally developed by the National Physical Laboratory, consist of bare wire specially mounted to avoid stress. Further tests have now shown them to be more stable than the conventional type using insulated wire.

3. Power Frequency.

(Division of Electrotechnology.)

(*a*) *Corona Detection.*—The presence of corona discharge is one of the most serious limitation in the development of electric measuring instruments for use at high voltages. It can also be one of the most important factors limiting the operational life of electrical components.

Two methods of detecting corona discharge have been investigated and developed to give increased sensitivity. In one case the high-frequency component of current in the discharge is observed using radio receiver methods refined for the purpose. When used in conjunction with a small spark gap this technique has been used to determine the voltage gradient on insulators and bushings.

In the other method corona has been detected in three-terminal air capacitors by observing the D.C. component in the discharge which has been shown to appear simultaneously with the onset of corona and the deterioration in power factor. In this way the upper voltage limit of capacitance standards can be determined.

(*b*) *Potential Divider.*—A new type of switched potential divider has been developed. It is similar to the Varley divider but allows more freedom in the choice of resistance values. In one particular design the divider requires only two different values of resistance coil in its construction.

4. Audio and Radio Frequency.

(Division of Electrotechnology.)

At the lower frequencies the major effort has been devoted to the development of special capacitors and transformers and their application in standards and measurements. At the higher frequencies an investigation of techniques for the production of high-quality coaxial line and microwave components has been made. Fundamental research into the application of microwave spectroscopy to the structure of molecules has continued.

(*a*) *An Absolute Standard of Capacitance.*—In all the more precise absolute determinations of the ohm by the various national laboratories the starting point has been an inductance whose value is calculated from its metrological dimensions. Various experiments in recent years have considerably improved the accuracy to which the velocity of propagation of light is known and this has revived interest in using a calculable capacitor as the starting point for an absolute determination of the ohm. This Laboratory is exploring the best physical form for such a capacitor and the

metrological techniques necessary to give the required accuracy. The various possible means of measuring precisely the spacing and dimensions of capacitor plates have been investigated. Electrical and electromagnetic techniques have been developed, which contribute greatly to the convenience and precision of measurement. These techniques, which are used in conjunction with optical interferometry, are suitable for remote control and can be applied without modification to the absolute determination of the capacitor in vacuum. The Division is collaborating with the Division of Metrology in a more general application of these methods to metrological measurements.

(*b*) *Audio-frequency Impedance Measurements.*—Equipment of basic importance in establishing the ohm in terms of a computed capacitor is the bridge which determines the relation between capacitance, resistance, and frequency. Two suitable bridges have been developed and effort is at present being concentrated on attaining the precision of 1 part in 10^7 desired for this determination.

As part of the same programme a bridge for the precision intercomparison of four-terminal resistors at frequencies ranging from 50 c/s to 5 Kc/s has been designed and a number of special components for this have been constructed.

Further improvements have been made to the amplifier detector units for use with such precision bridges and with the present equipment the sensitivity limit for capacitance measurements is now better than 10^{-7}pF. To obtain an accuracy of measurement corresponding to this sensitivity, very careful attention to bridge layout and other circuit details is necessary.

(*c*) *Stable Capacitors.*—In the previous annual report a new and highly stable type of three-terminal sealed capacitor was described. An even more promising capacitor employing an entirely different type of construction has now been developed and checked against the older units. After a small initial drift over a few days, the relative change has been less than 1 in 10^6 over a period of six months. Because of the extreme difference in construction this relative stability must also be regarded as a sound indication of the absolute stability of both types of capacitor.

(*d*) *Transformers.*—Considerable effort has been devoted to the development of precision ratio transformers and their application to standards and measurement work.

An outstanding development has been a transformer with secondary voltage ratios equal to the ratio of the number of turns to a precision of 1 part in 10^8. This has been achieved by using a toroidal core and shielding the primary winding with a succession of copper and "Permalloy" shields until a region of zero magnetic field is obtained in which the secondary windings can be located. The maximum difference between the induced voltages of two similar secondaries wound on such a core was about 1 part in 10^8.

A technique has been developed for winding a decade transformer with ten coils such that each coil occupies an equivalent position with respect to the core. The errors in a voltage divider constructed on this principle were less than 5 parts in 10^6. This divider was incorporated in a decade capacitance box to provide the equivalent of a finely-subdivided, high-quality, air dielectric capacitor. The present box has a total capacitance range of 1 pF subdivided to 1 μpF, achieved by switching a series of three-terminal air capacitors to the various taps of the voltage divider.

(*e*) *Switches with Low Contact Resistance.*—To exploit fully the advantages of precision transformers in bridge networks special switches with low contact resistance have been developed. A transformer bridge which measures resistances in the range 1 micro-ohm to 10 milli-ohms has been constructed to investigate the performance of such switches. Tests on commercial instrument switches have indicated the marked superiority of silver as a contact material, where low contact resistance is essential.

(*f*) *Capacitance Transducers.*—The development of simple but accurate transformer bridges and of small three-terminal capacitors of high stability has suggested the use of a number of simple capacitance transducers for mechanical and other physical measurements. Applications have included a sensitive diaphragm manometer, a liquid helium depth gange, and the height determination of a mercury column in a standard barometer.

(*g*) *Frequency.*—Considerable information has been obtained on the stability of the quartz crystal oscillators used in the laboratory's frequency standard by the development of a frequency comparator for comparing two frequencies to high precision over a short time interval. The accuracy of intercomparison achieved is of the order of 5 in 10^{12} in a period of 10 seconds and is expected to be improved still further.

The comparator has enabled the various frequency coefficients of the oscillators to be determined quickly and precisely and in consequence a number of design and operating improvements have been possible. When operating normally the oscillators now have short-term fluctuations in frequency of the order of 1 part in 10^{10}.

(*h*) *Microwave Measuring Equipment.*—The demand for measurements and calibrations in the microwave region is growing and several pieces of measuring equipment are being developed to extend the Division's facilities. These include cavity wavemeters, a stabilized noise generator, power-measuring equipment, and a frequency-stabilized klystron oscillator.

(*i*) *High-quality Microwave Resonators.*—High-quality cavity resonators at millimetre wavelengths require metals of the highest possible conductivity with an internal surface roughness not exceeding a few micro-inches. Mechanical buffing, electre polishing, electroplating, and evaporation of silver on to hardened steel have been tried. The last techniqne is promising but requires further investigation.

(*j*) *Electroforming of Microwave Components.*—Investigations have been made into the conditions necessary for the production of precision microwave components by the electroforming process. In this process, largely developed by Radar Research Establishment in England, an item in which a precision-bore hole is required is built up bv electrodeposition of metal on to a mandrel which has been ground and lapped to size, and which is then extracted.

A routine for cleaning and silver plating, by which bright, sound surfaces may be deposited against the mandrel, has been found, and part of the equipment necessary for even deposition of copper up to $\frac{3}{4}$ in. thick has been designed. The Division of Metrology has helped by advice and assistance in production of experimental mandrels with a satisfactory surface finish.

(*k*) *Sliding Contacts for Coaxial Lines.*—Adjustable length lines and short circuits are important elements in coaxial line measurements. The investigation of various types of sliding contacts and the possible metals and alloys is being conducted to develop good-quality sliding contacts with a reasonable working life.

(*l*) *Microwave Spectroscopy.* (i) *Experimental.*—The spectroscope has been further refined. In particular an automatic frequency-control system has been developed which effectively ties the klystron to the Division's frequency standard and enables the frequency of absorption lines to be determined to 1 part in 10^7.

The spectra of three simple triatomic molecules, carbonyl sulphide, water, and sulphur dioxide, are at present being investigated.

(ii) *Theoretical.*—This Division is collaborating with the Microwave Spectroscopy Laboratory of the Massachusetts Institute of Technology in an investigation of tritiated water. The appropriate spectroscopic constants of the molecules HOT, DOT, and TOT have been calculated and frequency predictions made of some 40 absorption lines expected in the microwave region.

5. Magnetic Measurements.

(Division of Electrotechnology.)

A new technique for measuring steady magnetic fields in the range of 10 to 4,000 oersteds has been developed. A very small ring of soft iron is placed with its axis parallel to the wanted field and is magnetically saturated twice per cycle by a 50 c/s. current flowing in a wire through the centre of the ring. The resulting alternating magnetic flux parallel to the unknown steady field is a measure of the latter and is detected by a coil wound over the ring.

6. Dielectric Investigations.

(Division of Electrotechnology.)

Work on the relationship between the chemical and physical structure of pure compounds and their dielectric properties has continued. Further experimental work on long-chain esters and hydroxy-compounds has helped to clarify the nature of their dielectric absorption. On the theoretical side significant contributions have been made in the theory of dielectric breakdown and in the general treatment of electron-lattice interactions in the solid state.

(*a*) *Wool Wax.*—Wool wax is a mixture of esters and from previous investigations of aliphatic esters in this Division it appeared likely that wool wax may provide the raw material for a useful dielectric at low frequencies. Measurements have shown that, with slight purification, a wax with good dielectric properties at low and audio frequencies can be obtained.

(*b*) *Aliphatic Compounds.*—The dielectric properties of several esters and one bromide have been investigated at radio and microwave frequencies. A clearer picture has now been obtained of the types of impurities which must be present in the crystal structure of these types of compound for them to have dielectric absorption.

Investigations have continued into the properties of an ester, butyl stearate, which will remain in the metastable α-phase for long periods. Previously-unknown phase changes between different α-phases have been revealed by these measurements.

(*c*) *Hydroxy-compounds.*—Investigations of the high dielectric loss in hydroxy compounds has continued. Pinacol hydrate, in which extensive hydrogen bonding would be expected, was shown to possess very large absorption with the relative permittivity changing from 3.3 to 51 through the dispersion region. This also results in a very high coefficient of permittivity with temperature and suggests the use of pinacol hydrate in a temperature-sensitive element for control or measurement of temperature.

(*d*) *Alkali Halides.*—In 1948 an American worker reported low-frequency dispersion in alkali halides and silver halides. The experimental evidence was rather slender and other workers had failed to confirm the effect. Crystals of a particular alkali halide (lithium fluoride) were obtained from three different sources, and low-frequency absorption was found in all the crystals and so confirmed the original worker's results. The properties of this absorption have been studied and quantitative information has been obtained about the ionic movements involved.

(*e*) *Cold-working Effects.*—It has been found that cold working can introduce dielectric loss into compounds that are normally loss free. In some respects the effects produced are analogous to the cold-working effects in metals as, for example, the tendency to return to normal on standing or on annealing.

(*f*) *X-ray Crystallography.*—The structure of the low temperature form of a secondary alcohol, 14-heptacosanol, has been determined and shown to contain chains of hydrogen bonds. The existence of a high temperature form has been demonstrated by single-crystal X-ray technique. Conditions for its occurrence were established by measuring the dielectric properties of material recrystallized at a number of fixed temperatures.

A preliminary examination of the crystallography of ethyl esters has been carried out.

A critical examination has been made of available X-ray data on the crystal structure of long-chain hydrocarbons. This has suggested another interpretation differing from that generally accepted and more compatible with the dielectric behaviour of their polar derivatives.

(*g*) *Theoretical Work.*—A new model has been proposed for a high-frequency loss in dielectric solids, and detailed calculations have been performed for the loss peak.

A new method has been devised for dealing with three-dimensional electron-lattice interaction. The method is essentially a generalization of Tomonaga's one-dimensional treatment and will be of considerable value in the theoretical investigation of solid-state problems, especially the superconductivity of metals.

In order to establish a more general theory of dielectric breakdown, the electron distribution functions in an insulator in the presence of a high electric field have been investigated. Distribution functions determined by previous workers, and apparently different, have been shown to be equivalent.

7. Special Investigations.

(Division of Electrotechnology.)

(*a*) *Physical Oceanography.*—The major effort of a senior officer of the Division is now devoted to the study of physical oceanography and the development of special instruments to assist the Division of Fisheries in this field of work (*see* Chapter XII., Section 5 (e)). A short visit was made to Europe and North America to attend conferences and study overseas research in physical oceanography.

Two instruments for the measurement of temperature and salinity have been developed.

The first is a portable unit for use in estuaries to depths of about 60 feet and the second is a more elaborate installation for the rapid measurement of temperature, salinity, and depth to 3,000 feet. The latter was given preliminary sea trials in April and is now being modified before final installation.

(*b*) *Radioactivity Meter for Drill Holes.*—There exists an urgent need for a suitable radioactivity meter to explore drill holes in uranium exploration. An instrument is being developed to mount on the end of existing drill rods and which sends its indication to the surface as a series of supersonic pulses along the drill rods and avoids the difficulty of providing separate electrical connexion to the surface.

8. Electrical Research Board.

(Division of Electrotechnology.)

The general objective of the Electrical Research Board is to foster fundamental electrical research in Universities and the training of graduates in research methods. Grants are made for projects suggested by the Universities.

The Board is representative of the Electricity Supply Association of Australia, the Universities, and the Organization. Financial support from member

organizations of the Electricity Supply Association has enabled the Board to support investigations in most of the Universities of Australia.

Investigations on the stability of power supply systems are being continued in the University of Adelaide with projects on network analysers and in the University of Melbourne by using model machine techniques. Transients are being studied in the University of Tasmania. In the University of Queensland work has been completed on the construction of the impulse generator and ancillary measuring and recording equipment; substantial progress has been made on thunderstorm studies and the preparation of an isoceraunic map. Work has been continued on electronic counters and amplifiers of extremely short time resolution and on the Hall effect in semiconductors in the University of Sydney where a new project on the dynamic stability of alternators has been started. The New South Wales University of Technology has also started a project on the representation of synchronous machines by electronic models. Investigation of the loss of electrode material from hot spots in electric arcs is being continued in the University of New England.

XXVII. RADIOPHYSICS.

1. General.

The techniques of radio and particularly its more recent offshoot, radar, have found employment in an ever-widening field of both scientific and industrial application. The use of pulse methods and the exploitation of very much higher frequencies than was possible a decade ago have provided scientists with new research tools of surprising versatility and power. The Division of Radiophysics is organized to carry out investigations in fields in which modern radio techniques have particular application. Chief among these are fundamental researches in cloud and rain physics and radio astronomy—fields in which it has already established an international reputation. The Division is also concerned with the study of physical properties of semi-conductors, and especially the devices known as "transistors" which are initiating a major revolution in electronic techniques; with the development of radio aids to navigation; and with high-speed computation by electronic means.

The Organization also undertakes research into the propagation of radio waves. This is done in collaboration with the Services, the Postmaster-General's Department, and the universities, under the direction of the Radio Research Board. Liaison between the various bodies carrying out research in the radio field and those who make use of the results of this research is facilitated by a Consultative Committee on Radio Research.

The work of the Division of Radiophysics is outlined in Sections 2, 3, and 7(*b*) of this Chapter and in Chapter XXXIII., Section 8; Chapter XXIX., Section 3; and Chapter XXV., Section 3. That of the Radio Research Board is described in Section 7(*a*) of this Chapter.

Division of Radiophysics.—The Division is predominantly engaged in fundamental research in rain and cloud physics and radio astronomy. A relatively smaller effort is devoted to a study of the physics of semi-conductors, in particular of transistors and their applications in electronic circuitry; and to some aspects of radio propagation that bear on radio communication and navigation.

The highlight of the past year has been a gift of 250,000 dollars from the Carnegie Corporation of New York toward the cost of building a giant radio telescope in Australia. This generous tribute to Australia's contributions to the new science of radio astronomy has been followed by an offer from the Commonwealth Government to meet half the cost of the proposed radio telescope (provided the remainder can be found from other sources).

During the year the Chief of the Division, Dr. E. G. Bowen, was invited by the Institute of Atmospheric Physics (of the University of Arizona) to attend a conference on cloud physics at Tucson, and while in the United States was consulted by the Advisory Committee on Weather Control which had been set up by President Eisenhower. Subsequently he paid a second visit at the invitation of the American Association for the Advancement of Science, to participate in an international symposium on "Problems of the Arid Lands". While in the United States he took the opportunity to investigate rain-making activities in that country, and problems connected with the construction of large radio telescopes. He also visited England for discussions with the British Meteorological Office on the whole question of cloud seeding, and with leading consulting engineers and designers on the projected giant radio telescope for Australia.

The Assistant Chief of the Division, Dr. J. L. Pawsey, attended, as an official Australian delegate, the XIth General Assembly of the International Union for Scientific Radio (U.R.S.I.) which was held at The Hague in August, 1954. At this conference, and at a Physical Society Conference on "The Physics of the Ionosphere" held at Cambridge in September, 1954, he presented accounts of recent work of the Division in the fields of radio astronomy and the ionosphere.

Radio Research Board.—The Board maintains a small permanent staff and also fosters approved projects in the universities where the opportunity and need for assistance exist. The Board's studies contribute useful knowledge in two ways: (i) by studies of radio propagation and all factors affecting radio communication paths; (ii) by study of air movements in the very high regions of the upper atmosphere by radio means.

These two subjects are closely interlinked and studies of both can best proceed simultaneously. The work of the Board during the past year has contributed materially to the knowledge of fundamental conditions and processes involved. New lines of attack are constantly being devised and improved equipment deployed in the investigations.

The Board's officers work in close co-operation with officers of the Ionospheric Prediction Service of the Department of the Interior, so that any new information on propagation may be utilized by them as rapidly as possible.

The year 1957-58 will be notable for intensive world-wide study of the ionosphere as part of the programme of the International Geophysical Year (I.G.Y.), in which some 38 countries will participate. The Board's Chief Scientific Officer is convenor of the National Committee for I.G.Y. which has been set up by the Australian Academy of Science to plan and co-ordinate Australia's programme of ionospheric, geomagnetic, auroral, and upper atmosphere researches both from the ground and by means of rocket ascents.

The Board's Chief Scientific Officer has been elected by the International Union of Radio Science to succeed Sir Edward Appleton as President of its Ionosphere Commission.

The Board's officers contributed five papers to the conference on the Ionosphere held at Cambridge in September, 1954.

The Board's laboratories and experimental station at Camden, New South Wales, are nearly ready for occupation; it is expected that a nucleus of staff will move in during October.

2. Radio Aids to Navigation.

(Division of Radiophysics.)

Two projects have been concluded in the past year. These were the investigation of a proposed method for navigating long-range aircraft by distance measurement, and the production and trials of equipment for the remote measurement of road-vehicle speed. An experiment to test the feasibility of finding the bearing of D.M.E. beacons from aircraft has been started.

(*a*) *Long-range Navigation by Distance Measurement.*—The ground transmitting stations previously set up at Townsville and on a coastal site near Sydney have been used to study the proposed method of distance measurement described last year. Aircraft measurements between Sydney and the mid-point of the path have confirmed the high potential accuracy predicted by the original oblique-incidence ionospheric experiment. An experimental aircraft equipment which indicates distance to the nearer station on a dial (after initial setting up by the operator) has been constructed and its performance is being evaluated. Owing to the nature of the ionospheric signals, it has been found that instrumentation of the system must be fairly complex and the maximum station separation is restricted to about 1,400 miles. Because of this limitation, it is not intended to carry the experiment beyond the present demonstration of the principle and the publication of the results.

(*b*) *Vehicle Speed Indication.*—Two radio-Doppler devices of the type developed by the New Zealand D.S.I.R. for the remote measurement of the speed of road vehicles have been constructed for the New South Wales Police Department. Laboratory and road trials over a period of six months have established the accuracy and reliability of the device and evidence on this aspect has been accepted by a Sydney Traffic Court.

(*c*) *Direction-finding on D.M.E. Beacons.*—A considerable number of D.M.E. (Distance Measuring Equipment) beacons are now in use on the Australian airways system. These enable a pilot to determine the distance to any selected beacon within range. A valuable addition to the system would be a method measuring also the bearing of the selected beacon. Direction-finding techniques on aircraft at the wavelength involved are, however, subject to error due to distortion of the waves by the aircraft structure. An experiment to determine the magnitude of these errors has been started in order that an assessment may be made of whether, by a relatively simple modification to the existing D.M.E. system, the desired supplementary information may be attained.

(*d*) *Oblique Incidence Propagation.*—The study of oblique pulse-transmissions on a frequency of 9.8 Mc/s between Sydney and Townsville in connexion with the Division's work on long-range distance measurement has been completed. Ionospheric phenomena investigated include the relation between oblique and vertical incidence propagation via the *E* and *F* layers, reflection by the night-time *E* layer, and the reflection, absorption, height variation, and fading characteristics of the day-time *E* layer.

3. Physics of Semi-conductors.

(Division of Radiophysics.)

The peculiar properties of semi-conductors—materials with properties intermediate between those of conductors and insulators—have been known for many years. The discovery, however, that certain semi-conductor devices, known as transistors, can perform many of the functions previously relegated exclusively to electronic valves, but at considerable savings in space, weight, power consumption, and heat dissipation, has led to intensive research and development in this promising field. Transistors are usually constructed from single crystal material of extremely high purity which has been "doped" with minute quantities of impurities to induce appropriate conductivity, which may be negative (n) or positive (p) type according to the impurity selected. The Division is investigating the basic physical properties of semi-conductor materials likely to provide transistor properties and the techniques required for the production of single-crystal material and for its subsequent doping. Sample quantities of experimental transistors are being produced so that their characteristics may be studied, and the circuit techniques required to make best use of the special advantages offered by these devices are being investigated.

(*a*) *Fundamental Investigations.*—During the year experimental work has continued on the growth of single crystals of germanium and silicon from the melt. A radio-frequency induction heater of 8 kW. output, built in the Division, has been used to melt pure silicon (melting point 1,415° C.), but to date it has not been possible to produce single-crystal material from this element.

From germanium crystals grown in the laboratory, experimental power junction transistors have been prepared, and their properties investigated. The units are capable of audio-frequency output greater than one watt; both p-n-p and n-p-n types have been constructed. Work has also been done on the production of high-frequency, point-contact transistors.

A theoretical treatment has been made of the physical phenomena involved in forming the collector of n-type germanium point-contact transistors. Results indicate that the current gain of such transistors is enhanced by the thermal diffusion of donor impurities into the germanium beneath the point contact. The donor ions change the potential barrier at the germanium surface in such a way as to enhance the flow of electrons from the collector for a given current of "holes" from the emitter. Experimental investigations with collectors of varying constitution support the theoretical conclusions.

The distribution of excess carriers of charge in filaments of extrinsic and intrinsic semi-conductors has been investigated theoretically, when there is a point source of excess carriers and the filament is subjected to an electric field. Preliminary experiments show good agreement with theory.

(*b*) *Transistor Circuit Development.*—Circuit development work is proceeding more freely now that adequate supplies of transistors are available from commercial sources. These are being supplemented by laboratory models for special purposes. Several applications of transistors are being studied, the most important being their use in a transistorized version of the airborne unit of the Australian Distance Measuring Equipment (D.M.E.). This unit, as manufactured at present, contains 45 valves, weighs 48 lb., and consumes 8 amperes at 28 volts.

Preliminary work indicates that transistor equivalents can be developed for the majority of the valve circuits. However, frequency and power limitations of currently available transistors prevent their use in the 200-Mc/s. transmitting oscillator, and there are one or two other functions which are difficult to achieve using transistors. It is hoped to produce an experimental transistorized unit of about one-fifth the weight and power consumption of the present production model. Development is now proceeding at the "breadboard" stage.

Other work which has been done includes the construction of test gear for transistors, a transistorized Geiger counter, and a transistorized portable radio. The uses of laboratory-model power transistors made in the Division are also being investigated. One important application for these transistors is in D.C. to A.C. power convertors which function with high efficiency on a low-voltage D.C. supply.

4. Mathematical Computation.

(Division of Radiophysics.)

This work is reported in Chapter XXX., Section 3.

5. Cloud and Rain Physics.

(Division of Radiophysics.)

This work is reported in Chapter XXVIII., Section 8.

6. Radio Astronomy.

(Division of Radiophysics.)

This work is reported in Chapter XXIX., Section 3.

7. The Ionosphere.

All long-distance radio propagation takes place through the ionosphere. The normal ionosphere is maintained in its ionized condition by radiation from the sun and therefore shows daily and seasonal variations. These are now reasonably well known for most regions of the earth. Less is known about the abnormalities, such as ionospheric storms, which disrupt radio communications from time to time, particularly when sunspots are active on the visible solar disk. The most common method used for studying the properties of the ionosphere involves reflection of radio signals. An alternative method consists of making use of radiation from cosmic radio sources and determining the effect produced by the ionosphere on this radiation as it passes through the earth's atmosphere. These effects may change with time either slowly or rapidly.

(*a*) *Investigations by the Radio Research Board.*—(i) *Morphology and Theory of Ionospheric Pressures.*—The work outlined in the last Annual Report has been further developed and has now reached a stage where the results can be put to practical use; this is being arranged through the Ionospheric Prediction Service of the Department of the Interior.

(ii) *Upper Air Winds.*—The investigations outlined in the last Report continue to yield results of considerable importance regarding the movement of disturbances of ionization both in the *E* and *F* regions of the ionosphere. These results are now being collated with those obtained in other regions of the earth in an attempt to derive the global pattern.

(*b*) *Investigations of the Division of Radiophysics.*—Observations of the spectrum of radio-star scintillations have been completed and analysed. This work has revealed several new features concerning the irregular structure of the upper atmosphere. In particular, the spectra have shown that scintillations are caused by the focusing effect of elongated irregularities in the ionosphere, several kilometres wide, which drift with horizontal velocities of the order of 100 m. per sec.

XXVIII. ATMOSPHERIC PHYSICS.

1. General.

The Organization is undertaking a number of basic studies of the physics of the atmosphere with the object of attaining a more fundamental understanding of the weather and the processes which control it. Meteorology is a public utility on which almost every phase of the community life depends in some way. It already provides a wide range of services to the public, but these can prosper and improve only against a background of basic research into the many problems yet unsolved. Furthermore, Australian scientists have played a leading part in a series of experiments in rain physics, which could lead to results of great interest for a continent such as Australia which lacks adequate water supplies over wide areas.

The Organization's major investigations in the field of meteorology are undertaken by the Division of Meteorological Physics at Aspendale, Victoria. This work includes studies on dynamic meteorology, general circulation, convection, and micrometeorology, including its application to frost prevention (*see* Sections 2-7 of this Chapter). The Division of Radiophysics, on account of its access to the radar techniques employed in this work, is engaged in a careful scientific study of the processes in nature which give rise to cloud and rain, and of possible methods of stimulating rainfall by artificial means (*see* Section 8 of this Chapter).

Division of Meteorological Physics.—The work of the Division is directed towards a closer understanding of the behaviour of the atmosphere, with a view not only to improving the prediction of its effects but also to utilizing them to the greatest advantage. The subject is essentially an international one and contributions were made during the year at meetings of the International Meteorological Association (U.G.G.I.), the Commonwealth Conference on Oceanography, the International Gliding Association, and at the Indian Ocean Science Congress which dealt with problems of more regional significance. Mr. L. P. Smith, Head of the Agricultural Meteorology Branch of the British Meteorological Office, visited Australia for two months as part of a tour to study applications of meteorology to agriculture and observe Australian practice in water conservation and irrigation. During the current year the former Section was raised to the status of Division.

2. General Circulation.

(Division of Meteorological Physics.)

Concentration has recently been on more local problems, but a summary of work on the general circulation was given to a special symposium on this subject at the U.G.G.I. Assembly in Rome. The novel features of the approach developed in the Division have played a part in orienting overseas work on this international problem.

Attempts to assess the water balance of the south-east part of the Australian continent by the same techniques, i.e., inflow and outflow from daily soundings of wind and humidity, have so far proved inconclusive, but there are hopes for success if the soundings can be improved in number and accuracy.

3. Dynamic Meteorology.

(Division of Meteorological Physics.)

Work in dynamic meteorology centres on selected problems of a long-term nature concerned in the full-scale processes of weather. Selection is decided on basic rather than day-to-day importance, though the work should still lead to improved standards and techniques in analysis and forecasting.

The study of interactions between monsoonal and general circulations in the Australian region is being continued and an investigation of the sequence relations in summer pressure patterns has been completed. An unexpected temporary reversal has been found in January of the continental low-pressure system (heat low), which tends to be strongest and furthest south in December and February.

Marked diurnal wind oscillations over the West Australian and Queensland hinterland are being examined as an indication of the daily cycle of convective mixing.

Investigations into the nature of discontinuities in temperature, moisture, and wind, associated with cold fronts and similar phenomena, have been continued on an extensive scale. The classification of fronts in Western Australia based on radio soundings has been completed, and related to the behaviour of pressure systems subsequently affecting south-east Australia. Preliminary examinations of "cool changes" affecting south-east Australia had emphasized the need for more special observational data. The Division has now enlisted the help of voluntary observers, and has

installed recording instruments at key places and on ships and aircraft, while special measurements have been obtained at Aspendale and from the Victorian Country Fire Authority whose operational problems are allied to this study. The multiple structure of the "cool change" has now been established over a wide region as composed of prefrontal windshift or pressure-jump lines or both, as well as of a cold front in the normal sense. The modification of heated continental air while temporarily over water south of Australia has been found to be an important process. The work, so far exploratory and selective, should lead to a more systematic study of summer weather changes and a better recognition of the precise processes at work.

4. Convection.

(Division of Meteorological Physics.)

Theoretical work has provided a solution for the velocity and temperature fields above a continuous source of heat in calm conditions. Very different behaviour results by day from that by night when a ceiling is formed above which the gas cannot penetrate. Experimental work is on hand to test the theory. Applications may then be made to orchard heating, to industrial pollution (which is now under notice in parts of Australia and an urgent health problem overseas), to flying and visibility conditions, and to the physics of rain showers.

5. Micrometeorology.

(Division of Meteorological Physics.)

The principal aim in micrometeorology has been an understanding of the mechanics of turbulent processes in the lower atmosphere by detailed observation of the fine structure of temperature, motion, and water vapour content of the air. The exchange of energy between the earth's surface and the atmosphere is a main factor in the production of air masses of different characteristics which originate many weather phenomena. The work relates also to the water balance of crops and reservoirs, the microclimate of vegetation, and allied subjects. The techniques reported previous y have been improved, mainly to extend the range of the study to lighter wind conditions.

The first phase, now largely completed, has greatly clarified the laws of transfer of meteorological properties, and this now allows concentration on more specific aspects. Observations on days of strong heating have disclosed a marked and comparatively sudden change in the heat disposal mechanism with decrease in wind speed. The theoretically derived laws for the heat loss by free convection, which operates at the lighter wind speeds, have been confirmed at the same time.

Spectral analyses of fluctuation records have been carried out to find the intensities associated with different sizes (scales) of eddy. The scale of vertical air movements increases roughly in proportion to height, while the change for horizontal velocity and temperature is less marked. The great change in scale between day and night has for the first time been quantitatively studied. The work also throws light on the adequacy of response time of the recording system and more exact information will come from a current investigation using simultaneously instruments of varying response.

The study of conditions on clear nights has been supplemented by observations of radiative transfer at two levels to determine the relative importance of this to turbulent heat transfer.

Agricultural research requires a method of measuring evaporation from growing crops over varying time intervals. Progress has been made with an instrument to provide this, by adapting the method employed in the basic micrometeorological work. The vertical velocity meter is almost completed, and a suitable fast-response hygrometer is being evolved based on the principle developed by the Division of Physics.

Measurements of wind speeds up to 500 feet on a radio mast have shown that gustiness increases less rapidly with height than the mean wind speed. This is relevant to the economical design of tall structures and is of some importance both in aircraft structural problems and in landing and take-off problems.

Since most of the earth's surface is water, more fundamental knowledge is required of the source of atmospheric energy derived from interaction with the ocean; this has reciprocal interest as a controlling factor in ocean currents and temperatures, and hence in problems of fisheries. Exploratory studies to extend the work on turbulent transfer to the atmosphere-ocean problems are now well advanced, and it is hoped to carry out some preliminary trials at sea during the coming year.

The Division has continued to advise other organizations on micrometeorological aspects of their work. It has undertaken the construction of a number of fine-structure probes, and provides a calibration service for instruments of this type and for anemometers and air meters for outside bodies.

6. Frost Prevention.

(Division of Meteorological Physics.)

Trials on the use of wind machines for frost prevention were continued, mainly in grape-vines with a ducted fan now available commercially ("JETOM"). The performance of this machine was generally satisfactory at strong inversions, indicating a favorable mixing pattern with the narrow high-speed air jet, but poor at weak inversions. The effect of increasing the height of the duct outlet will be investigated during the coming season.

In earlier work using large fans attention was focused on the amount of warm air drawn down, the effect in mixing the inversion layer at a distance being regarded as secondary. Work with fans delivering progressively smaller quantities of air, but with similar amounts of kinetic energy, has reversed the emphasis, much of the temperature increase at low levels being due to mixing at a distance. This conclusion has been confirmed by the lack of substantial improvement when a ducted fan was fitted with a furnace to heat the emerging air. Accordingly a ducted fan delivering a narrow high-speed air jet is being erected at the main testing site at Griffith.

7. Ozone Investigation.

(Division of Meteorological Physics.)

Atmospheric ozone, though small in total amount, makes an important contribution to the radiation balance of the atmosphere and there is a close connexion between ozone content and latitude, season, and synoptic situation. Measurements have been made for some years under international auspices in a number of countries, mainly in the northern hemisphere. It is proposed to establish a network of three stations in the south-east of Australia. The necessary adjustments and calibrations of one of the instruments have been completed and observations started in Melbourne.

8. Cloud and Rain Physics.

(Division of Radiophysics.)

An experimental investigation of the physical processes involved in the formation of cloud and rain was initiated in 1947 following a successful demonstration that rain could be induced from supercooled clouds by treating them with dry ice. The broad aim was to obtain not only a sound understanding of the basic physical mechanisms at work that could be used to

provide a guide to methods of artificial stimulation that might be expected to be successful, but also a background against which the practicability of producing useful rain might be assessed.

In previous years the Division's efforts have largely been devoted to measuring the properties of clouds, particularly those associated with natural rain, and, while some seeding experiments were carried out, these were mainly confined to single clouds. The results of this work, which have been described in previous Reports, have led to a realization of the important role in the atmosphere played by naturally-occurring, dust-like particles known as "nuclei" and to an understanding of how, under appropriate conditions, individual clouds can be made to rain by supplying substitutes when the natural nuclei are absent or ineffective. During the past year the emphasis has been on obtaining further detailed information on the occurrence and behaviour of these natural nuclei (condensation nuclei for warm clouds, freezing nuclei for supercooled clouds), and on the investigation, supported by field trials, of methods of artificial seeding by which rainfall over an area (as distinct from single clouds) might be increased.

(*a*) *Cloud Formation and Cloud Properties.*—(i) *Warm Clouds—"Project Shower".*—In October and November, 1954, members of the Division participated in an international research project undertaken in the Hawaiian Islands for the purpose of studying the physics of rainfall from "warm" clouds. In these clouds, which are a frequent source of rain in Australia, particularly in coastal areas and in the north, the ice phase is not involved and precipitation results from the coalescence of the small cloud droplets to form rain. However, many of the details of the rain process are not understood and the role played by nuclei originating in sea-spray has only recently been realized. Hawaii is an excellent location for a scientific study of such clouds since the rainfall is high and of frequent occurrence, and falls on the slopes of readily accessible mountains whose tops reach above the clouds. Furthermore, adequate airport facilities and ground meteorological services are available.

"Project Shower" was sponsored by the Woods Hole Oceanographic Institute, Boston, Massachusetts, the Meteorological Department of the Pineapple Research Institute of Hawaii, and Hawaiian Sugar Planters' Association in Honolulu. The Office of Naval Research of the United States Navy provided funds for the purpose and the Radiophysics Division was invited to participate. Several other organizations were also represented.

The Australian group was responsible for all the measurements in cloud of temperature, liquid water content, and cloud droplet spectra, the measurements being made in the specially fitted Royal Australian Air Force Dakota which was flown to Hawaii for the duration of the project. In addition, it made measurements of cloud droplet charge and salinity of rain from stations on the mountain side. Other groups measured rainfall distribution, winds, atmospheric electricity, sea-salt nucleus spectra, raindrop spectra, nitrogen content of the rain, and the trace constituents of the atmosphere.

Despite an unusually fine stretch of weather during November, a great deal of information was gathered. This mass of data is now being reduced and tabulated.

(ii) *Electric Charge on Cloud Droplets.*—The charge carried by cloud droplets is of importance in its influence in increasing probabilities of coalescence between cloud droplets and the consequent production of rain. Apparatus has been constructed in which the movement of droplets in a strong electric field can be photographed. Preliminary trials indicate that cloud droplets usually carry appreciable positive charges, negative charges only occurring when the ice phase is present in clouds. Further work is planned.

(iii) *Shattering of Salt Crystal Nuclei.*—The giant hygroscopic nuclei in the atmosphere consist almost always of sea-salt crystals, which exist as droplets when the relative humidity of their environment exceeds 75 per cent. Laboratory experiments, using a special expansion chamber in which the humidity could be varied, showed that the drying out of microscopic salt droplets produced a large number of condensation nuclei which are probably submicron salt crystals released during the crystallization process. Thus a considerable multiplication in numbers of nuclei originating from the ocean can take place in an air mass in which, for example, large updrafts and downdrafts occur.

(*b*) *Rain.*—Observations of natural rain have largely been those incidental to the carrying out of other experiments. Work during the past year has been mainly confined to a more detailed study of the apparent connexion between rainfall and dust of meteoric origin mentioned briefly last year, together with some further work on coalescence between droplets.

(i) *The Effect of Meteoric Dust on Rainfall.*—Evidence was found in the previous year for a possible connexion between rainfall and meteor activity. It appeared that for a number of places in both the northern and southern hemispheres there was a strong tendency for excess rainfall to occur some 30 days after the date of known meteor streams. It was thought that this interval of 30 days represented the time taken by the small meteoric particles to settle to the lower regions of the atmosphere where they could operate as freezing nuclei and thus, under favorable meteorological conditions, either intensify rainfall or induce it to fall.

More detailed statistical analysis using data from many more places scattered over the world has continued to support this hypothesis and still further statistical studies are planned.

Measurements were made in the month of January of the daily variation of natural freezing nucleus content in the free atmosphere, in order to see if in fact the concentration increased following the passage of the earth through a meteor stream. Measurements were made in aircraft from Richmond, New South Wales, and also from Tucson, Arizona, United States of America, using equipment supplied and installed by the Division. In addition, measurements were made on the top of a mountain in the Hawaiian Islands. The results are now being analysed, but first indications suggest that more data are required before definite conclusions can be drawn.

As a further check on the theory, an attempt was made to obtain optical measurements of the dust content of the upper atmosphere. An atmospheric layer containing dust contributes more to the scattered light from the sun than does the pure air of a dust-free region. Consequently during twilight, as the earth's shadow crosses such a layer, the rate of change of illumination undergoes variations. This quantity was therefore measured, the height of the corresponding region being deduced from the time between the increase in illumination and sunrise or sunset. Completely clear skies and a dry climate being essential, most of the observations were made near Alice Springs. The measurements were very successful in showing that the presence of dust accumulations in the atmosphere could be recognized not only in the troposphere but up to heights of 80 kilometres. Dust was found to be associated with temperature inversions. Near the tropopause it varied widely in amount, being closely associated with the passage of weather systems. Dust in the vicinity of the known temperature inversion at

about 80 kilometres, although very patchy, showed variations from day to day that appeared to be related to the advent of meteor streams. Some more refined experiments of a similar nature are to be made shortly.

Practically all reliable data on meteor streams have been collected in the northern hemisphere. A few meteor observations by radar were therefore made during the year at a site near Sydney to check whether there were any prominent streams which affect the southern hemisphere only, and to provide up-to-the-minute information on meteor activity. A survey of meteor activity by other methods had, however, already been commenced at Adelaide University. The Division's direct observations have therefore been discontinued and instead, with the co-operation of the University of Adelaide, arrangements have been made for the continuance of the work at Adelaide by appointing the officer responsible for it to the staff of the Division.

(ii) *Theoretical and Experimental Investigation of Coalescence.*—The study of high collection efficiencies of nearly equal drops has now been extended to cover the drop diameter range 100 to 200 microns. The collection efficiency shows no significant change in this region, the average value being fourteen. Experiments show no tendency for water droplets to bounce as sometimes has been suggested.

A mathematical investigation of the statistical fluctuations in the time intervals between collisions has been made. It has been shown that previous theory based on average rates of growth greatly over-estimate the time required for drops of raindrop size to appear in a cloud. A typical cloud model containing 10 per cent. of its water in droplets of twice the volume of the remainder has sufficient drops to form rain produced by coalescence in about 5 as compared with about 33 minutes on previous theories. This saving in time presents a challenge to the theory of giant salt nuclei in which this stage of growth is supposedly by-passed by large nuclei growing rapidly by condensation processes.

(*c*) *Artificial Rain Formation.*—Consideration has been given during the past year to cloud seeding trials on a larger scale than hitherto. in the light of knowledge of the mechanisms of rain formation derived from earlier work. The material offering the best prospects of successful and economic application to the problem of increasing rainfall over an area appears to be silver iodide, and several preliminary experiments were carried out. In order that it may be possible to conduct further routine seeding experiments over a longer period, the Division has purchased an Anson aircraft and arrangements are well in hand for its modification and fitting out for seeding with silver iodide by means of smoke generators built in to each wing tip.

(i) *Silver Iodide.*—A comprehensive series of experiments is being carried out to determine the effectiveness of this material as a means of increasing rainfall. Most of these experiments are aimed at increasing the rainfall over an area and the assessment of the results will be on a statistical basis by a comparison of the rainfall with past years' records. Hence it is anticipated that some time will elapse before the success or otherwise of the experiments can be ascertained.

In co-operation with the Victorian State Electricity Commission, in September, 1954, seeding was commenced from a ground generator on Mount Stanley in north-eastern Victoria, with a view to increasing the precipitation in the Kiewa catchment area. The burner is operated whenever the wind is in the appropriate direction and clouds have developed.

In early December, 1954, seeding from an aircraft at medium altitudes was carried out near Cloncurry and in the Gulf country in Queensland. Many flights were made and the silver iodide smoke was dispersed over a wide area. Recently this type of seeding has been started again in the Riverina and Monaro districts in co-operation with the Snowy Mountains Hydro-electric Authority.

A few preliminary seeding experiments were made in which silver iodide was dispersed from a Vampire jet-propelled aircraft at high altitude. However, weather conditions were not often favorable and no significant results were observed.

(ii) *Electrical Techniques.*—It is known from laboratory experience that when cloud droplets are electrically charged, their behaviour and chance of colliding with each other and of coalescing are strongly influenced. It is also known from field observations that many clouds consist of droplets which already have small positive charges on them. The presence of a comparatively small number of negatively charged drops in such clouds might profoundly change their behaviour and rain might result. Investigations are being made into the possibilities of artificially producing the requisite numbers of charge droplets in suitable clouds with a view to causing the droplets to coalesce and form rain.

XXIX. EXTRATERRESTRIAL PHYSICS.

1. General.

The new science of radio astronomy—the study of the universe by means of radio waves—is now recognized as an important and integral part of astronomy itself. Apart from providing information which supplements that obtained by optical methods, it has led to entirely new discoveries which could not have been made by the methods of classical astronomy. A more recent development, which is certain to shed light on the origin and structure of galaxies—including that to which the Earth belongs—is the discovery of a radio "spectral line" at a wavelength of 21 cm., due to atomic hydrogen.

Radio astronomy has formed a major part of the research programme of the Division of Radiophysics (*see* Section 3 of this Chapter). Studies of the ionosphere are carried out by the Radio Research Board (*see* Chapter XXVII., Section 7). Work on solar radiation is carried out by the Division of Physics (*see* Section 2 of this Chapter) and cosmic ray investigations at the University of Tasmania (*see* Section 4).

2. Solar Physics.

(Division of Physics.)

(*a*) *Emission of Radiation from Hot Atmospheres.*—Theoretical studies of the emission of radiation from hot atmospheres has been continued by an investigation of the emission spectrum of helium and hydrogen mixtures at temperatures above 10,000° K.

(*b*) *Physical Conditions in the Chromosphere and in Prominences.*—The non-appearance of the helium D_3 line and the intensity of the helium absorption line λ 10830 Å in the spectrum of the Sun's disk may be explained, on the above analysis, if the temperature of the main absorbing region is about 11,000 to 14,000° K., a conclusion consistent with an analysis of measurements made elsewhere of the D_3 emission at an elevation of 1,000 km. above the solar limb.

Physical conditions in prominences have been derived from the analysis of values found by other observers of the half-widths and intensities of a large number of $H\alpha$ lines. The results, namely, temperatures of 10,000 to 15,000° K. and electron concentrations of 10^{10} to 5×10^{10} per c.c., while of the same order as those obtained by other investigators, are of greater accuracy. It has also been shown that a considerable part of the $H\alpha$ radiation from prominences is due to the diffuse reflection of chromospheric radiation.

(*c*) *Magneto-hydrodynamics.* — The stability of a uniform current flowing along a magnetic field and confined between a pair of parallel planes has been examined by the method of normal modes, and conditions for stability derived for selected cases. The eigen frequencies of compressible regions of uniform magnetic field bounded by plane parallel and cylindrical surfaces have also been found.

(*d*) *Observations.*—Observations of the chromosphere and prominences by time-lapse photography using a Lyot filter have been continued on a routine basis.

3. Radio Astronomy.

(Division of Radiophysics.)

During the year several important discoveries relating to the Sun and galaxy have been made. These discoveries were based on the use of new types of equipment designed and built by the Division. Similar types of equipment following Australian designs have now been built in other countries, and it was with one such unit—a "Cross" aerial, built at Washington —that electrical storms on the planet Jupiter were recently detected.

Although the problem of obtaining high resolving power for surveying the galaxy at the longer wavelengths, and for studying the Sun at all useful wavelengths, has been solved by the invention of special methods of observation, the study of the galaxy at the shorter wavelengths appears to require the use of a very large radio telescope, capable of being directed to different parts of the sky and to follow the movement of the celestial sphere. The Carnegie Corporation of New York, in making a generous gift of 250,000 dollars toward the cost of such an instrument, has led to an offer by the Commonwealth Government that it would meet half the cost provided the remainder can be found from other sources. Several private donations have already been received and the requisite financial support seems assured. A booklet outlining the proposals for a giant radio telescope for Australia has been prepared and it is hoped that technical details for the proposed instrument will be finalized and the project launched during the coming year.

(*a*) *Radio Waves from Outside the Solar System.*— The universe is composed mainly of hydrogen gas, much of which is in a very tenuous state. It is in this tenuous gas that the principal part of the radiation which is studied in radio astronomy originates. A study of the angular distribution in the sky of this radiation, combined with a study of its spectrum, is revealing the distribution of matter in our galaxy and also is providing information on the structure and composition of other galaxies.

The mechanism of origin of all the various types of cosmic radio emission is not yet fully understood. Two of the mechanisms, however, have been explained satisfactorily—that of the line-emission from neutral atomic hydrogen and the so-called thermal emission from ionized hydrogen. There is a third type of emission which has been explained in terms of radiation from high-velocity electrons moving in the weak magnetic fields of interstellar space. If this explanation is valid—and new observations are being used to test it—then there is probably a close connexion between this type of cosmic radiation and cosmic ray particles.

(i) *Discrete Sources and Background Radiation.*— The new "Cross" aerial, developed recently by the Division, is being used at a wavelength of 3.5 m. in an attempt to solve some of the outstanding problems of radio astronomy. Because of the high directivity of the aerial—far higher than anything used previously at such a wavelength—celestial radio sources have been resolved, for the first time, from their surroundings.

The distribution of radio emission from the Magellanic Clouds has been studied in detail; for the first time it has been possible to compare directly the distribution of radio emission with the various stellar populations constituting a galaxy. From these observations, and from those relating to eleven other nearby galaxies and to selected parts of the Milky Way, it has been possible to show that the principal radio emission from a galaxy at the longer wavelengths originates in two different types of source, having distinctly different distributions. An analysis of these observations has lent support to the theory mentioned earlier in which this radio emission is produced by high-energy electrons moving in magnetic fields in interstellar space.

A second "Cross" aerial system, larger than the first, and designed to operate at the relatively long wavelength of 15 m., is being constructed. This aerial will have arms nearly 4,000 feet long and a beam width of about 1.5°.

At the shorter wavelengths, a general survey of galactic radio emission has been made at a wavelength of 50 cm. The aerial available for this is too small to make the survey comparable in resolution with those that will be undertaken with the two "Cross" aerials, but until a larger parabola is available this survey will provide useful interim information for studies of the spectrum of cosmic radiation.

(ii) *Line Emission from the Galaxy.*—Observations of the 1420 Mc/s. line emission from neutral hydrogen atoms provide information about the motions as well as the distribution in the sky of interstellar hydrogen. Since the hydrogen roughly follows the distribution of the visible stars, it can be used as a "tracer" to study the large-scale structure of stellar systems or galaxies.

A detailed study of the southern part of our galaxy is now in progress and the results, when combined with those from similar studies in the northern hemisphere, will produce a three-dimensional map of the spiral structure of the galaxy.

While this survey is in progress, a new and more elaborate receiving system is being constructed. This new equipment will allow observations to be made very much more rapidly than any in use at present, because all parts of the spectrum will be obtained simultaneously.

(*b*) *Radio Waves from the Sun.*—By means of two multiple interferometers arranged at right angles, the Sun has been scanned stripwise by aerial beams which are about 1/20° in width, over a large range of angles. From these observations the radio brightness distribution over the disk of the undisturbed Sun has been determined for a wavelength of 0.2 m. It has been found that in the equatorial regions of the Sun there is marked limb-brightening, whereas no limb-brightening is found in the solar polar regions.

Following this work, one of the interferometers was modified to work at a wavelength of 0.6 m. and was used to study the one-dimensional brightness distribution at this wavelength. The presence of limb-brightening at this wavelength, also, was confirmed.

In order to enable the results of observations of brightness distribution to be interpreted in terms of physical conditions in the solar atmosphere, a number of theoretical brightness distributions were derived for different wavelengths and for a range of temperatures and densities in the solar atmosphere. These are being compared with observations.

Spectral observations of solar radio bursts in the frequency range 40–240 Mc/s. are continuing, and are being used to determine the character of corpuscular streams from the Sun. A recent quantitative analysis of velocities has supported the suggestion made here that the fastest of these streams represent the cosmic rays of solar origin which bombard the earth about 1 hour after a solar eruption.

A special interferometer, 1 km. wide, is being constructed to allow these disturbances to be located on, and followed across, the Sun's disk.

A new technique has been developed for measuring polarization at a large number of frequencies. This is enabling the characteristic properties of solar radio disturbances — spectrum and polarization — to be correlated in detail. The collation in the Division of the results of daily radio observations of the Sun, obtained in many different countries, has continued, and the results are published by the International Astronomical Union.

(c) *Radio Waves from the Planet Jupiter.*—A search has been made for evidence of radio emission from the planet Jupiter following an announcement from the United States of America that strong but intermittent signals, having the general impulsive character of atmospherics, had been picked up from it at a wavelength of about 15 m.

A radio telescope having very precise directional characteristics at this wavelength is required to establish with certainty that such signals are, in fact, coming from Jupiter. A "Cross" aerial capable of this performance at an adjacent wavelength has been under construction for some time but is not yet in operation. Strong atmospheric-like signals have, however, been detected intermittently with less accurate equipment, and a search of earlier records taken in 1950-51 shows several periods of severe "interference" consistent with an origin in the planet Jupiter. In neither case is the directional accuracy sufficient to exclude other possibilities, but these observations lend general support to the idea that powerful radio emissions do emanate from at least one other member of the solar system in addition to the Sun.

(d) *Theoretical Studies.*—Theoretical work has centred largely on problems of the origin and transmission of electromagnetic waves in an ionized gas, such as is found in the sun's atmosphere and in the vicinity of hot stars. An investigation of the harmonic structure of longitudinal plasma oscillations has been made, and the results have been used to show the mode of origin of "harmonic bursts" from the sun.

The question of the growth of electromagnetic waves in an ionized medium has been investigated and it has been found that a number of proposed mechanisms for this are untenable.

The various types of waves that may be generated in an ionized medium in the presence of a magnetic field have been studied and found to reduce to only four types.

4. Cosmic Ray Research.

(University of Tasmania.)

The analysis of data from counter telescopes at Hobart and Macquarie Island has continued, using equipment built at the University for the cosmic ray research programme of the Australian National Antarctic Research Expedition.

The diurnal variations of the east-west difference of intensity are being studied. The analysis of the Macquarie Island data is expected to give new information concerning the influence of solar cosmic rays on the diurnal variation of the penetrating component at sea level.

It has been observed that the east-west asymmetry has been decreasing since 1948, whereas the theory of the high latitude asymmetry predicts no change at a given latitude. The implications of this are being examined.

A diurnal variation of the barometer coefficient for the penetrating radiation has been observed, using data from a vertical counter telescope of high counting rate, in operation at Hobart. Work is in progress to determine the significance of this for the correction of the diurnal variations of intensity for surface pressure changes.

Air mass effects on the barometer coefficients of cosmic rays at Macquarie Island have been examined and two papers on this subject have been published in the *Australian Journal of Physics.*

XXX. MATHEMATICS AND MATHEMATICAL STATISTICS.

1. General.

Mathematical work plays an important part in all phases of the Organization's research programmes. A separate Division of Mathematical Statistics is maintained to provide workers in the various Divisions and Sections with specialized help in planning their researches and analysing their experimental results.

Work on mathematical instruments and mechanical and electrical methods of computation is undertaken in the Section of Mathematical Instruments. Work on computing equipment is also undertaken in the Division of Radiophysics (*see* Section 3 of this Chapter).

Division of Mathematical Statistics.—There has been consolidation in the Divisional programme during the past year, with firm establishment of the new centres inaugurated, in May, 1954, at Coal Research, Armidale, and Brisbane, and further extension of activities in the Wool Textile Research Laboratories.

In addition to co-operative investigations within the Organization, described in appropriate sections throughout the Report, and the provision of advisory assistance to an increasing number of outside bodies, including universities, and Commonwealth and State departments, the Division has continued its own programme of research in various theoretical aspects of mathematical statistics having important practical applications, and certain of these are summarized below.

The Powers-Samas punched-card installation now at Divisional head-quarters is a major addition to equipment, making practicable various large-scale investigations which have been planned for some time.

Mathematical Instruments Section.—The work of the Section has been based on the solution of differential equations occurring in research and industrial problems. The differential analyser has been in almost continuous operation, and the only technical developments have been those intended to improve its reliability and speed. It has been found impracticable to undertake the solution of problems involving the respective application of large numbers of numerical data, such as periodic rainfall or river flow records. These problems are of considerable industrial significance, and the Section is co-operating with the University of Sydney in the development of an electronic digital differential analyser, primarily to meet this need.

2. Analysis.

(Division of Mathematical Statistics.)

(a) *Multivariate t-Distribution.*—Work on this exact distribution has been continued, and has led to the derivation of the sampling distributions of all the known statistics which may be obtained from it; the latter distributions provide the means for making a variety of exact tests of significance with small samples.

(b) *Recovery of Inter-block Information in Quasi-factorial Designs.*—Hitherto, only approximate methods have been available for recovering inter-block information in quasi-factorial designs with incomplete data. In the period under review, the exact procedure for combining the weighted inter- and intra-block information in a single estimate of a missing observation has been obtained for all types of balanced incomplete block designs, of square, triple, and cubic lattices, and of the lattice squares.

(*c*) *Design and Analysis of Two-phase Experiments.*—It often happens in experimental work that the effects of different treatments cannot be measured directly, and a further stage of testing is required in order to evaluate them. Examples of this type of situation are studies of the effect of conditions of growth of parent material on resistance to disease or productivity of progeny; the survival of nodule bacteria under various conditions of storage and appraised by inoculating appropriate legume seedlings; and the effect of various treatments on virus multiplication in leaf tissue, the concentration of virus being ascertained by lesion counts on indicator plants.

The object of this investigation was to establish the principles for the design of such experiments, and to develop appropriate methods of statistical analysis.

(*d*) *Improvement of Resolution in Paper Electrophoresis.*—The mathematical theory of diffusion has been applied in a study of the factors affecting resolution of component fractions in paper electrophoresis of serum proteins. It has been shown that resolution can be enhanced by subjecting the proteins on a paper strip to an electric force which decreases progressively from the point of application of the serum, eventually becoming constant. (In practice, this effect is induced by shaping the paper appropriately.) The decreasing electric force exerts a focusing effect which partially offsets the loss in power of resolution due to the finite size of the applied spot or band of serum.

(*e*) *Statistical Analysis of Designs with Incomplete Data.*—A simplified procedure of obtaining equations for missing values has been developed for the analysis of incomplete data. It has been shown, in particular, that there is only a limited number of different coefficients which can occur in the matrix of the normal equations. The number is small, even for complex designs such as the lattices. Tables of these coefficients have been prepared for some of the standard designs, to facilitate construction of the matrix of normal equations.

In the analysis of completed data, certain component sums of squares are always too large, but simple formulae for calculating the necessary reductions are available for the several designs based on blocks, with any admissible number of missing observations. For designs based on Latin squares, corresponding formulae are available only when a single observation is missing. A useful theorem, which yields concise correction formulae for sums of squares when several values are missing in designs based on Latin squares, has been proved.

(*f*) *Statistical Studies on Sheep Breeding.*—These collaborative investigations between the Division of Mathematical Statistics and the Division of Animal Health and Production have continued and are reported in Chapter VII., Section 14.

(*g*) *Other Investigations.*—In addition to the above projects, investigations are in progress on multivariate analysis, regression analysis, the mathematical problems arising in chemical kinetics, and the development of a comprehensive test of goodness of fit for the combination of contingency tables of frequency distributions.

3. High-speed Computation.

(Division of Radiophysics.)

During the year the decision was made to transfer the electronic computer to a centre where the facilities it provides might be of the greatest usefulness. The University of Melbourne showed interest in acquiring such a machine and it has therefore been made available to the University of Melbourne on extended loan: it will be operated jointly by the Departments of Mathematics and Physics. The computer, after an overhaul, was transported to Melbourne by road and is now being re-assembled at its new site.

Theoretical and numerical studies of several diffraction problems in optics (having application, for example, to large parabolic antennas), and of the hydrodynamics of spherical droplets falling in a viscous fluid at a range of Reynolds numbers (yielding useful information on their interaction and coalescence) were completed during the year, prior to closing down the electronic computer for transport to Melbourne. Useful work has also been done on the presentation of problems to an electronic computer by means of "routines" so that the machine itself automatically programmes the computation.

4. Differential Analyser.

(Mathematical Instruments Section.)

The more important problems undertaken on the differential analyser during the year include:

(*a*) Studies of the capability and of the steady-state stability of alternators in an interconnected electric power system. These studies were undertaken in association with the Electricity Commission of New South Wales.

(*b*) The solution of a hydraulic problem in a hydro-electric system, undertaken on behalf of the Snowy Mountains Hydro-electric Authority.

(*c*) A study of forced and free motion of a bubble in an infinite fluid, carried out in association with the University of Sydney and the New South Wales University of Technology.

(*d*) Solutions of the negative Emden polytropes, in connexion with the theory of globular clusters. These solutions were obtained for the Commonwealth Observatory.

XXXI. PUBLICATIONS AND INFORMATION.

1. General.

The Organization's research results are made available through various channels.

Formal scientific publication is supplemented in several ways; by the preparation of films (Section 4 of this Chapter) which may, for example, give a farmer or extension officer more help in diagnosis of animal diseases than would a list of clinical data; by the continous and close contact with industry of officers of the Divisions and Sections, through whom much information—derived from the literature, accumulated knowledge and experience, and current research—is disseminated; by the provision of facilities for guest workers in laboratories; by the publication of trade circulars, newsletters, and articles for trade journals; by press releases; by lectures and short courses of specialized training; and by the organization of specialist conferences.

The application of research in the primary industries is being assisted by the work of the Agricultural Research Liaison Section established in 1951 (Section 3 of this Chapter).

Other sections of this Chapter describe the work of the Organization's libraries (Section 5); the Translation Section (Section 6); the Information and Documentation Sections (Section 7); and the overseas Liaison Offices (Section 8).

2. Publications.

In collaboration with the Australian National Research Council, the Organization now publishes the following eight scientific periodicals:—

Australian Journal of Agricultural Research—Six issues a year.
Australian Journal of Applied Science—Issued quarterly.
Australian Journal of Biological Sciences—Issued quarterly.
Australian Journal of Botany—Issued as material becomes available.
Australian Journal of Chemistry—Issued quarterly.
Australian Journal of Marine and Freshwater Research—Issued as material becomes available.
Australian Journal of Physics—Issued quarterly.
Australian Journal of Zoology—Issued as material becomes available.

General editorial policy is decided by an Editorial Board comprising Dr. N. S. Noble (Chairman), Professor J. S. Anderson, Professor Sir Macfarlane Burnet, Professor L. H. Martin, and Professor J. G. Wood. Editorial Advisory Committees are responsible for editorial matters affecting each individual journal, and members of the Board serve on appropriate journal committees.

The Royal Australian Chemical Institute collaborates in the publication of the *Australian Journal of Chemistry*, the Institute of Physics (Australian Branch) collaborates in the publication of the *Australian Journal of Physics*, and the Australian Veterinary Association and the Australian Institute of Agricultural Science collaborate in the publication of the *Australian Journal of Agricultural Research*.

The Organization's research results are published in the abovementioned journals, in its bulletins and the technical papers of its Divisions and Sections, and in special series such as the "Land Research" series and the "Soil Publication" series. Many research papers are also contributed by officers of the Organization to specialized scientific journals both in Australia and overseas.

Th journals listed above are open to receive contributions of merit from research workers, irrespective of country or of the organization to which they are attached. Many papers from workers in Australian universities and a limited number from overseas have been published, and the marked increase in the annual volume of the journals represents growing support from all sources.

A complete list of scientific papers published during the year by officers of the Organization will be found in Chapter XXXIV.

3. Liaison Between Agricultural Research and Extension Work.

The Agricultural Research Liaison Section was formed mainly to ensure that the Organization's research results were made available to State departments of agriculture for use in their extension work with farmers. The work of the Section is concerned chiefly with marshalling important research material and presenting it in suitable form through publications and at conferences with State agricultural authorities.

Officers of the Section must necessarily keep in touch with both research and extension organizations through personal contacts, including visits to research centres and attendance at conferences. Discussions with State authorities are leading to a closer research-extension linkage regarding the special problems of important regions.

(*a*) *Publications.*—The quarterly periodical "Rural Research in C.S.I.R.O." is meeting a demand for a concise description of aspects of the Organization's research which can have important practical applications.

Important subjects are selected as major themes for each issue. The September number, for example, dealt particularly with surveys, and described those concerned with soils, land use, ecology, and the beef cattle industry. C.S.I.R.O. work concerned with various aspects of hydrology formed the theme of the December issue. This was followed in March by a review of the 1955 Australian Weed Control Conference, accompanied by articles on weed control by chemicals and insects. The Section is placing major emphasis on integrating material for extension. Subjects requiring more detailed treatment are appearing in the Organization's "Leaflet" series, and important research results are described in press releases.

(*b*) *Conferences.*—Conferences between research and extension officers were held to deal with recent research results requiring more detailed explanation and discussion. In November, 1954, the third of a series of conference-tours of important regions was held in the Coonalpyn Downs of South Australia. About 30 officers concerned with agricultural administration, research, and extension travelled for five days through the area to study the results of investigations by C.S.I.R.O., the South Australian Department of Agriculture, and the University of Adelaide.

Later in the same month the Section participated in the organization and conduct of a pasture irrigation conference convened by the Victorian Department of Agriculture. This was probably the most representative gathering of irrigationists yet held in Australia. It comprised over 80 officers from departments of agriculture, water supply and land settlement authorities, universities and research organizations from all States, as well as overseas representatives. Three days were spent in formal lecture sessions in Melbourne and Werribee, and members then travelled for six days through the main pasture irrigation districts of Victoria and the Riverina, concluding on the ninth day with a review session at Cobram.

The Section helped in the planning and conduct of other conferences arranged by the Organization, in particular the Beef Export Conference held in Brisbane in March, 1955. It assisted the New South Wales Department of Agriculture in publishing the proceedings of the 1953 conference-tour of the Northern Tablelands and has made preliminary arrangements with the Department for other regional conferences of this nature.

The Section is preparing a report on the principles and procedures for organizing liaison-type conferences.

(*c*) *Films.*—The Section works with the Film Unit in the production of films on rural topics and assists it with the art work associated with the Unit's general activities.

(*d*) *Displays.*—In addition to work associated with publications, conferences, and films, the Section's art department is being increasingly used to help with displays. The Section co-operated with the Division of Food Preservation and Transport and the Dairy Research Section in preparing a large exhibit for the Melbourne Better Food Exhibition in February, 1955. Help in matters of design, illustration, and lettering was also given to other branches of the Organization.

(*e*) *Inquiries.*—About 1,000 inquiries were received during the year from extension workers, research officers, schools, pastoral companies, banks, individual farmers, and others interested in the agricultural development of Australia. Many were answered direct and others were referred to appropriate research or extension authorities. In several instances, the required

information was supplied in the form of a report based on material obtained from several different authorities and collated by the Section. Mimeographed statements prepared in this way are available on the following subjects:—

Bibliography of C.S.I.R.O.'s Publications on Irrigation, Drainage, and Related Subjects.

Phosphorus Supplements for Cattle.

Selected References on C.S.I.R.O. Pasture Research.

Regeneration of Salted Areas, with Special Reference to Salt-tolerant Vegetation.

4. Film Unit.

During the year the following films were completed and released.

War Against the Rabbit—16 mm., colour, sound, screening time 23 minutes. Produced for the Victorian Department of Crown Lands and Survey, the film shows how a farmer in collaboration with his neighbours and the Vermin and Noxious Weeds Branch tackles the problem of complete eradication of rabbits from his property.

Meiosis—16 mm., colour, sound, screening time 11 minutes. This completely animated film was produced in collaboration with the Animal Genetics Section, and describes the complicated chromosome-halving cell division preceding the formation of sperm and egg cells.

Acute Phalaris Staggers in Sheep—16 mm., black and white, sound, screening time 11 minutes. Produced in collaboration with the Division of Biochemistry and General Nutrition, as a record of the progression of the outward symptoms of the acute phase of the disease. This film supplements an earlier film which dealt with the chronic stages of phalaris staggers.

Ragwort Control—16 mm., colour, silent, screening time 18 minutes. Produced in collaboration with the Victorian Department of Crown Lands and Survey. The new methods to control ragwort are contrasted in the film with those previously used by landholders. Modern equipment and hormone sprays are far more effective and economical, and their use has been brought within the means of all farmers.

Homes for the Inland—16 mm., colour, sound, screening time 12 minutes. The Film Unit helped the M.I.A. Agricultural Service of the New South Wales Department of Agriculture in the final stages of the production of this film which outlines the methods of pisé house construction and the essential features in the design of homes for inland areas.

Films on the following subjects are in the course of production:—

The Mutton Birds of Bass Strait—16 mm., colour, sound.

Two Blades of Grass—pasture improvement in southern Australia—16 mm., colour, sound.

The Penguins of Macquarie Island—16 mm., colour, sound.

Supply and Drainage Ditches—16 mm., colour, sound.

Cine film records have been made of the following research activities:—

(i) The arrival of Zebu cattle in Australia for the Division of Animal Health and Production.

(ii) Slow-motion analysis of hay raking equipment for the Agricultural Engineering Section, Melbourne University.

(iii) Air movements for the Division of Meteorological Physics.

5. Libraries.

Miss E. L. Archer, M.Sc., who built the library network on such a firm foundation, retired from the position of Chief Librarian during the year. Her place has been taken by Miss B. C. L. Doubleday, M.A.

In the latter half of 1954 a separate library under the charge of a Senior Assistant Librarian was set up in the Western Australian Regional Laboratory. The Libraries of the Wildlife Survey Section, Canberra, and Sheep Biology Laboratory, Prospect, are similar instances of new small libraries set up during the year. This brings the total of libraries within the Organization to 45.

The General Supplement to the 2nd Edition of the Union Catalogue of Scientific and Technical Periodicals in the Libraries of Australia, which will bring it up to date from 1946 until July, 1955, will, it is hoped, be ready for the printer by the end of 1955. The next project will be a union list of books held by the Organization's libraries which will probably be issued first in mimeographed form.

In addition to taking over the responsibility for the Abstracts of Published Papers and List of Translations, Head Office Library now houses the Index to C.S.I.R.O. publications. It is hoped to maintain a complete file of all published papers of officers of the Organization, whether written before or after they joined the staff. Except for the small quantity of material that is confidential, this should provide not only the Organization but any member of the public with readily accessible data on any aspect of work done by officers. Further, the complete reorganization of the reading room in Head Office library has made available an additional 500 feet of space which can be made to house both additional material and more readers. Its resources are available to any serious readers be they research workers or students, but this fact does not seem to be sufficiently widely known. Within certain limitations, too, books and periodicals are lent to kindred establishments.

6. Translation.

The Translation Section has carried out written and oral translation for officers of the Organization.

The Section has continued to act as Australian agent for the Index of Translations of the British Commonwealth Scientific Office. A reference card index of available translations has been kept, and has occasionally prevented duplication. A large number of cards relating to translations held by the Library of Congress of the United States have been received and added to the Index, but the supply has now ceased. Microfilm copies of all translations made by this Section from Russian have been prepared for the National Science Foundation, United States of America.

The languages that can be handled by the Section are: German, Dutch, Latin, French, Italian, Swedish, Norwegian, Danish, Spanish, Portuguese, Russian, Icelandic, Polish, Ukranian, Serbo-Croat, Slovene, Lettish, Hebrew, and Hungarian. For other languages use must be made of outside translators.

7. Technical Inquiries.

In addition to the large number of inquiries received by Divisions and Sections, many are also directed to Head Office. Where it is appropriate, such inquiries are sent on to specialists either within the Organization or elsewhere. If this is not possible, replies are provided from Head Office. Some changes in arrangements for handling these inquiries were made during the year, and a large part of the work involved is now being undertaken by members of the library staff

8. Overseas Liaison Offices.

The Organization has Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London) and the British Commonwealth Scientific Office (North America). These offices maintain close contact with overseas scientific developments and also act as bases for visitors and research students from the Organization and for other visiting scientists.

In London, the Chief Scientific Liaison Officer has represented Australian interests at a number of international and United Kingdom scientific conferences and committees, and has thus developed closer contacts and understanding on many matters. The London Office has materially assisted with regard to the enlistment of research staff, not only in the United Kingdom but also in other European countries, especially Holland. The Washington Office has also contributed greatly to Australian representation at conferences and meetings held in the United States of America.

XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. Executive.

Sir Ian Clunies Ross, C.M.G., D.V.Sc. (*Chairman*).
F. W. G. White, C.B.E., M.Sc., Ph.D. (*Chief Executive Officer*).
S. H. Bastow, D.S.O., B.Sc., Ph.D.
H. J. Goodes, O.B.E., B.A.
A. B. Ritchie, M.A.

2. Advisory Council.

Chairman.

Sir Ian Clunies Ross, C.M.G., 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—Professor J. G. Wood, Ph.D., D.Sc.
Western Australia—Professor E. J. Underwood, B.Sc. (Agric.), Ph.D.
Tasmania—S. L. Kessell, M.B.E., M.Sc., Dip.For.

Co-opted Members.

D. T. Boyd, C.M.G.
L. B. Bull, C.B.E., D.V.Sc.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
The Hon. O. McL. Falkiner, M.L.C.
W. A. Gunn, C.M.G.
D. R. Hawkes.
Sir Edward Lefroy.
D. Mackinnon.
I. M. McLennan, B.E.E.
Emeritus Professor Sir John Madsen, B.E., D.Sc.
Professor L. H. Martin, C.B.E., Ph.D.
Professor D. M. Myers, B.Sc., D.Sc.Eng.
Professor M. L. Oliphant, M.A., Ph.D., D.Sc., LL.D., F.R.S.
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., Agr.Dip.

3. State Committees.

New South Wales.

Professor J. P. Baxter, O.B.E., B.Sc., Ph.D. (*Chairman*).
Emeritus Professor Sir Henry Barraclough, K.B.E., V.D., B.E., M.M.E.
F. S. Bradhurst.
V. J. F. Brain, B.E.
J. N. Briton, B.Sc., B.E.
Sir Harry Brown, C.M.G., M.B.E.
Professor H. R. Carne, D.V.Sc.
S. F. Cochran.
The Hon. O. McL. Falkiner, M.L.C.
W. R. Hebblewhite, B.E.
E. L. S. Hudson.
The Hon. Sir Norman Kater, M.L.C., M.B., Ch.M.
J. F. Litchfield.
Professor P. R. McMahon, M.Agr.Sc., Ph.D.
Professor J. R. A. McMillan, D.Sc.Agr., M.S.
Emeritus Professor Sir John Madsen, B.E., D.Sc.
J. Merrett.
C. St. J. Mulholland, B.Sc.
Professor D. M. Myers, B.Sc., D.Sc.Eng.
R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
R. P. Okeden.
J. G. Peake.
A. R. Penfold, A.S.T.C., F.R.A.C.I.
Professor D. W. Phillips, B.Sc., Ph.D.
H. F. Prell.
L. A. Pockley, B.V.Sc.
Associate Professor F. H. Reuter, Ph.D.
T. C. Roughley, B.Sc.
J. P. Tivey, B.A., B.Sc., B.E.
J. Vernon, B.Sc., Ph.D.
Emeritus Professor W. L. Waterhouse, M.C., D.Sc.Agr., D.I.C.
Emeritus Professor R. D. Watt, M.A., B.Sc.
C. M. Williams, O.B.E.

Victoria.

R. S. Andrews, D.Sc. (*Chairman*).
D. T. Boyd, C.M.G.
N. K. S. Brodribb, C.B.E., F.R.I.C., M.I.P.E., A.R.A.C.I.
L. B. Bull, C.B.E., D.V.Sc.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
J. R. S. Cochrane, B.Sc.
G. A. Cook, O.B.E., M.C., M.Sc., B.M.E.
Professor J. N. Greenwood, D.Sc., M.Met.E.
Sir Russell Grimwade, C.B.E., B.Sc.
Emeritus Professor E. J. Hartung, D.Sc.
H. Herman, D.Sc., M.M.E., B.C.E.
Professor E. S. Hills, D.Sc., Ph.D., D.I.C., F.R.S.
R. A. Hunt, D.S.O., B.C.E.
Associate Professor G. W. Leeper, M.Sc.
Emeritus Professor Sir Peter MacCallum, M.C., M.A., M.Sc., M.B., Ch.B.
D. Mackinnon.
I. M. McLennan, B.E.E.
Professor L. H. Martin, C.B.E., Ph.D.
H. A. Mullett, B.Agr.Sc.
G. B. O'Malley, B.Met.E.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
D. E. Thomas, D.Sc.
Professor J. S. Turner, M.A., Ph.D., M.Sc.
Professor S. M. Wadham, M.A., Dip.Agr.
W. E. Wainwright.
L. J. Weatherley, M.A.
Emeritus Professor H. A. Woodruff, B.Sc.

Queensland.

A. F. Bell, M.Sc., D.I.C. (Chairman).
Professor T. K. Ewer, B.V.Sc., Ph.D.
V. Grenning.
W. A. Gunn, C.M.G.
R. L. Harrison.
Professor D. A. Herbert, D.Sc.
C. H. Jamieson.
Professor T. G. H. Jones, D.Sc.
N. J. King.
A. McCulloch, M.E.

Professor W. V. Macfarlane, M.A., M.D., Ch.B.
O. O. Madsen, M.L.A.
J. F. Meynink.
J. Michelmore.
I. W. Morley, B.M.E., B.Met.E.
O. E. J. Murphy, M.D., M.Ch.M.
Professor M. Shaw, M.E., M.Mech.E.
B. Flewell-Smith.
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M. A. Mawby, F.S.T.C., D.Sc.(Honorary), Zinc Corporation Ltd., Melbourne (*Chairman*).
W. E. Baragwanath, O.B.E., A.S.M.B., Melbourne.
Associate Professor H. H. Dunkin, B.Met.E., Department of Mining, University of Melbourne.
R. B. Mills, B.Sc., Electrolytic Zinc Co. Ltd., Melbourne.
G. B. O'Malley, B.Met.E., Melbourne.
K. S. Blaskett, B.E., Ore-dressing Investigations, C.S.I.R.O. (*Secretary*).

29. Kalgoorlie Mining Advisory Sub-committee.

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R. C. Buckett, B.E., Lake View and Star Ltd., Kalgoorlie, Western Australia.
R. A. Hobson, B.Sc., School of Mines, Kalgoorlie, Western Australia.
A. A. McLeod, M.Aus.I.M.M., M.A.I.M.E., North Kalgurli (1912) Ltd., Kalgoorlie, Western Australia.

30. Consultative Committee on Brown Coal Research and Development.

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H. R. Brown, B.Sc.(Eng.), Coal Research Section, C.S.I.R.O.
E. A. Bruggeman, Dr. Ing., Gas and Fuel Corporation of Victoria.
G. B. Gresford, B.Sc., A.M.T.C., C.S.I.R.O.
E. A. Hanson, Ph.D., Gas and Fuel Corporation of Victoria.
F. H. Roberts, Dip.Mech.Eng., Dip.Elec.Eng., State Electricity Commission of Victoria.
R. W. Urie, B.Sc., S.M., Division of Industrial Chemistry, C.S.I.R.O.
I. W. Wark, D.Sc., Ph.D., Division of Industrial Chemistry, C.S.I.R.O.
F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O.
B. E. Mummery, B.Sc., C.S.I.R.O. (*Secretary*).

31. Mineragraphic Committee.

F. L. Stilwell, O.B.E., D.Sc., Melbourne.
W. E. Wainwright, A.S.A.S.M., Australasian Institute of Mining and Metallurgy.

32. Electrical Research Board.

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W. H. Connolly, B.E.E., B.Com., State Electricity Commission of Victoria.
F. J. Lehany, M.Sc., Division of Electrotechnology, C.S.I.R.O.
Professor D. M. Myers, B.Sc., D.Sc.Eng., University of Sydney.
F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O. (*Conjoint Secretary*).
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33. Radio Research Board.

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Comdr. (L) R. R. W. Humbley, R.A.N., Department of the Navy.
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Group Captain A. G. Pither, R.A.A.F., Department of Air.
Professor H. C. Webster, D.Sc., Ph.D., University of Queensland.
F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O.
R. v.d. R. Woolley, M.A., M.Sc., Ph.D., F.R.S., Commonwealth Observatory.
B. E. Mummery, B.Sc., C.S.I.R.O. (*Secretary*).

34. Meteorological Research Consultative Committee.

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F. Loewe, Ph.D., University of Melbourne.
Emeritus Professor Sir John Madsen, B.E., D.Sc., University of Sydney.
C. H. B. Priestley, M.A., Sc.D., C.S.I.R.O.
G. B. Gresford, B.Sc., A.M.T.C., C.S.I.R.O. (*Secretary*).

35. Consultative Committee on Radio Research.

F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O. (*Chairman*).
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E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.O.
Col. A. W. de Courcey Browne, M.I.R.E.(Aust.), A.M.Brit.I.R.E., Department of the Army.
B. G. Gates, B.Sc., Ph.D., D.I.C., Department of Supply.
Cmdr. (L) R. R. W. Humbley, R.A.N., Department of the Navy.
A. H. Kaye, B.Sc., Telecommunications Advisory Committee.
R. R. Long, B.E.E., Overseas Telecommunications Commission (Aust.).
N. J. McCay, B.Sc., Postmaster-General's Department.
A. J. McKenzie, M.E.E., Australian Broadcasting Control Board.
Emeritus Professor Sir John Madsen, B.E., D.Sc., Radio Research Board, C.S.I.R.O.

D. F. Martyn, D.Sc., Ph.D., A.R.C.S., F.R.S., Radio Research Board, C.S.I.R.O.
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D. J. Medley, M.Sc., Department of Civil Aviation.
G. H. Munro, D.Sc., Radio Research Board, C.S.I.R.O.
R. E. Page, F.I.R.E., A.M.I.E.(Aust.), Telecommunications Advisory Committee.
Group Captain A. G. Pither, R.A.A.F., Department of Air.
L. S. Prior, B.Sc., Bureau of Mineral Resources, Geology and Geophysics.
E. J. Stewart, B.Sc., Postmaster-General's Department.
B. E. Mummery, B.Sc., C.S.I.R.O. (*Secretary*).

36. Building Research Committee.

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S. H. Bastow, B.Sc., Ph.D., C.S.I.R.O.
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T. J. Cavanagh, Cement and Concrete Association, Sydney.
S. A. Clarke, B.E., Division of Forest Products, C.S.I.R.O.
J. W. Drysdale, Commonwealth Experimental Building Station, Sydney.
D. V. Isaacs, M.C.E., Commonwealth Experimental Building Station, Sydney.
J. R. Barned, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

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Professor J. C. Jaeger, D.Sc., M.A., Australian National University.
T. Pearcey, B.Sc., Division of Radiophysics, C.S.I.R.O.
Professor T. G. Room, M.A., F.R.S., University of Sydney.
F. W. G. White, C.B.E., M.Sc., Ph.D., C.S.I.R.O.
H. A. Wills, B.E., Department of Supply.
M. Beard, B.Sc., B.E., Division of Radiophysics, C.S.I.R.O. (*Secretary*).

38. Belmont Technical Committee.

D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O. (*Chairman*).
J. Griffith Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.
W. A. T. Summerville, D.Sc., Department of Agriculture and Stock, Queensland.
W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland.
R. S. Wilson, United Graziers' Association of Queensland.
J. F. Kennedy, M.Agr.Sc., Division of Animal Health and Production (*Secretary*).

XXXIII. STAFF.

The following is a list of the staff of the Organization as at 30th June, 1955. The list does not include clerical staff, typists, technical assistants, and miscellaneous workers.

1. Head Office.

(Head-quarters: 314 Albert-street, East Melbourne.)
Chairman—Sir Ian Clunies Ross, C.M.G., D.V.Sc.
Chief Executive Officer—F. W. G. White, C.B.E., M.Sc., Ph.D.
Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Assistant Executive Officer—H. C. Forster, M.Agr.Sc., Ph.D.
Secretary (General Administration)—F. G. Nicholls, M.Sc.
Secretary (Industrial and Physical Sciences) and Acting Secretary (Agricultural and Biological Sciences)—G. B. Gresford, B.Sc., A.M.T.C.
Secretary (Finance and Supplies)—M. G. Grace, A.A.S.A.
Assistant Secretary (Staff)—D. T. C. Gillespie, M.Sc.
Assistant Secretary (Agricultural and Biological Sciences)—P. F. Butler, M.Sc.Agr.
Senior Principal Research Officer—J. E. Cummins, B.Sc., M.S.
Senior Research Officer—W. F. Evans, B.Sc.
Senior Research Officer—J. F. H. Wright, B.Sc.
Research Officer—Miss J. Dunstone, B.Sc., Dip.Ed.
Research Officer—B. E. Mummery, B.Sc.
Technical Officer—J. D. Dover, A.S.T.C.
Technical Officer—I. D. Pullen, B.Sc.

Editorial—
Editor—N. S. Noble, D.Sc.Agr., M.S., D.I.C.
Principal Research Officer—A. E. Scott, M.Sc.
Senior Research Officer—R. W. Crabtree, B.Sc.
Senior Research Officer—Miss M. Walkom, B.A.
Research Officer—Miss L. F. Plunkett, B.Sc.
Research Officer—G. J. Wylie, B.A., B.Sc.
Technical Officer—L. A. Bennett, B.Sc.
Technical Officer—G. A. Forster, B.Sc.

Library—
Chief Librarian—Miss B. C. L. Doubleday, M.A.
Librarian—Miss J. Conochie, B.Sc.
Librarian—Miss L. J. Davey, B.Sc.
Librarian—Miss I. J. McPhail, B.Sc. (at Brisbane).
Librarian—Miss H. Storie, B.Sc.
Union Catalogue of Periodicals, Editor—Miss A. L. Kent.

Accounts—
Accountant—D. J. Bryant, A.A.S.A.

Finance—
Finance Officer—R. W. Vincy, A.A.S.A., A.C.I.S.

Stock Records—
J. M. Short, A.A.S.A., A.C.I.S.

Orders and Transport—
V. H. Leonard, J.P.

Staff—
Staff and Industrial Officer—H. E. Waterman, A.A.S.A.

Records—
P. Knuckey.

Publications—
Senior Technical Officer—T. R. Hunter.

Liaison Overseas—
London—
Chief Scientific Liaison Officer—W. Ives, M.Ec.
Senior Research Officer—A. B. Hackwell, B.Agr.Sc.
Research Officer—J. P. Shelton, M.Sc., A.B.S.M.

Washington—
Principal Research Officer—E. J. Drake.
Research Officer—A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D.

Translation Section—
Senior Translator—A. L. Gunn.
Senior Translator—E. Feigl, Ph.D.
Senior Translator—F. P. Just, D.U.P.
Translator—Mrs. M. Slade.
Translator—H. E. Kijlstra, B.A.
Translator—C. Wouters, Ph.D.(Lit.) (at Sydney)

Film Unit—
Senior Research Officer—S. T. Evans, B.Sc.
Architectural—
Architect—W. R. Ferguson, B.E.
Draughtsman, Grade II.—T. O. Jewell.

2. Secretaries of State Committees.

New South Wales—
A. J. Higgs, B.Sc., Division of Radiophysics, University of Sydney.
Victoria—
F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.
Queensland—
W. W. Bryan, M.Sc.Agr., Plant and Soils Laboratory, Brisbane.
South Australia—
A. Packham, B.V.Sc., Division of Biochemistry and General Nutrition, University of Adelaide.
Western Australia—
R. P. Roberts, M.Sc. (Agric.), Department of Agriculture, Perth.
Tasmania—
D. Martin, D.Sc., "Stowell", Stowell-avenue, Hobart.

3. Agricultural Research Liaison Section.

(Head-quarters: 314 Albert-street, East Melbourne.)
Officer-in-charge—R. R. Pennefather, B.Agr.Sc.
Principal Research Officer—K. Loftus Hills, M.Agr.Sc.
Senior Research Officer—J. L. Gillespie, B.Agr.Sc.
Research Officer—A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D. (seconded).
Technical Officer—J. J. Lenaghan, B.Agr.Sc.

4. Animal Genetics Section.

(Head-quarters: University of Sydney.)
Officer-in-charge—J. M. Rendel, B.Sc., Ph.D.
Senior Research Officer—A. S. Fraser, M.Sc., Ph.D.
Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.
Research Officer—B. L. Sheldon, B.Agr.Sc.(Hons.).
Research Officer—W. R. Sobey, B.Sc., Ph.D.
Technical Officer—J. Nalukowyj.
Technical Officer—K. E. Turnbull, B.A.

5. Division of Animal Health and Production.

(Head-quarters: Cnr. Flemington-road and Park-street, Parkville, Melbourne.)
At Divisional Head-quarters, Melbourne—
Chief—D. A. Gill, M.R.C.V.S., D.V.S.M.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.
Assistant Divisional Secretary—N. M. Tullob, M.Agr.Sc.
At Animal Health Research Laboratory, Melbourne—
Assistant Chief of Division and Officer-in-charge—T. S. Gregory, D.V.Sc., Dip. Bact.
Assistant Chief of Division—A. W. Turner, O.B.E., D.Sc., D.V.Sc.
Senior Research Fellow—L. B. Bull, C.B.E., D.V.Sc.
Principal Research Officer—D. Murnane, D.V.Sc.
Principal Research Officer—R. H. Watson, D.Sc.Agr.
Principal Research Officer—A. T. Dick, D.Sc.
Senior Research Officer— J. E. Peterson, B.V.Sc.
Senior Research Officer—A. W. Rodwell, M.Sc., Ph.D.
Senior Research Officer—A. T. Dann, M.Sc.
Research Officer—J. B. Bingley, D.A.C.
Research Officer—Miss C. E. Eales, B.Sc.
Research Officer—Miss M. J. Monsbourgh, B.Sc.
Research Officer—H. M. Radford, B.Sc.
Research Officer—Miss V. E. Hodgetts, B.Sc.
Research Officer—J. S. McKenzie, B.Sc.
Research Officer—P. Plackett, B.A.
Technical Officer—I. McCance, B.Sc.
Technical Officer—J. J. Spencer.
Technical Officer—N. E. Southern.
Technical Officer—J. R. Etheridge.
Librarian—Miss F. V. Murray, M.Sc.
At Poultry Research Centre, Werribee, Victoria—
Senior Research Officer and Officer-in-charge—F. Skaller, M.Agr.Sc., B.Com.
Research Officer—J. A. Morris, B.Sc.Agr., Ph.D.
Research Officer—T. E. Allen, B.Sc.
Technical Officer—Miss L. W. Bőbr, M.Sc.(Agr.).
At McMaster Animal Health Laboratory, Sydney—
Senior Principal Research Officer and Officer-in-charge—D. F. Stewart, D.V.Sc., Dip.Bact.
William McIlrath Fellow in Animal Husbandry—M. C. Franklin, M.Sc., Ph.D.
Senior Principal Research Officer—H. McL. Gordon, B.V.Sc.
Research Officer—M. D. Murray, B.Sc. (Vet.Sc.), M.R.C.V.S.
Research Officer—W. K. Warburton, LL.B., B.Sc.(Hons.), Ph.D.
Research Officer—R. I. Sommerville, M.Sc.Agr.
Research Officer—P. R. Whitfeld, B.Sc.(Hons.), Ph.D. (on study leave).
Research Officer—C. H. Gallagher, B.V.Sc. (on study leave).
Research Officer—Miss J. H. Koch, M.D.
Research Officer—P. K. Briggs, B.Sc.Agr.(Hons.).
Research Officer—L. E. A. Symons, B.V.Sc.
Research Officer—J. H. Thomas, B.V.Sc.
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Ian McMaster Scholar—B. A. Panaretto, B.V.Sc.
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Technical Officer—H. V. Whitlock.
Technical Officer—G. C. Merritt.
Technical Officer—B. L. Campbell, A.S.T.C.
Technical Officer—K. J. Farrington, A.S.T.C.
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At Sheep Biology Laboratory, Prospect, New South Wales—
Assistant Chief of Division and Officer-in-charge—I. W. McDonald, B.V.Sc., B.Sc., Ph.D.
Technical Secretary—J. H. Elliott, B. Sc.(Hons.).
Principal Research Officer—P. G. Schinckel, B.V.Sc., R.D.A.
Principal Research Officer—K. A. Ferguson, B.V.Sc., Ph.D.
Principal Research Officer—R. L. Reid, B.Sc.Agr. (Hons.), Ph.D.
Principal Research Officer—Mrs. M. H. Fallding, M.Sc., Ph.D. (at the McMaster Laboratory).
Senior Research Officer—A. A. Dunlop, M.Agr.Sc., Ph.D.
Senior Research Officer—L. T. Wilson, B.Sc.
Research Officer—J. P. Hogan, B.Sc.Agr.(Hons.).
Research Officer—B. F. Short, M.Agr.Sc., Ph.D.
Research Officer—G. Alexander, M.Agr.Sc.
Research Officer—W. Strauss, B.Chem.E.
Research Officer—A. L. C. Wallace, B.Sc.
Research Officer—R. H. Weston, B.Sc.Agr. (Hons.).
Research Officer—A. G. Lyne, B.Sc. (at the McMaster Laboratory).
Senior Technical Officer—A. H. Brook, B.V.Sc.
Senior Technical Officer—H. R. Lindner, B.V.Sc.
Technical Officer—S. H. Buttery, B.Sc.
Technical Officer—W. T. Outch.
Technical Officer—Mrs. L. Norgard.
Technical Officer—S. S. Y. Young, B.Agr.Sc., F.S.T.C.
Librarian—Miss J. S. Hicks.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Senior Research Officer and Acting Officer-in-charge—J. F. Barrett, B.V.Sc., H.D.A.
Senior Research Officer—W. H. Southcott, B.V.Sc.
Senior Technical Officer—R. W. Hewetson, B.V.Sc.
Technical Officer—J. M. George, B.Sc.Agr.

At F. D. McMaster Field Station, Badgery's Creek, New South Wales—
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Research Officer—J. M. Doney, B.Sc.(Hons.).

At Veterinary Parasitology Laboratory, Yeerongpilly, Queensland—
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Senior Research Officer—P. H. Durie, M.Sc.
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Technical Officer—R. K. Keith, Dip.Ind.Chem.

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Senior Research Officer—N. M. T. Yeates, B.Sc.Agr.(Hons.), Ph.D.

At National Field Station, "Gilruth Plains", Cunnamulla, Queensland—
Officer-in-charge—C. H. S. Dolling, R.D.A., B.Ag.Sc.
Technical Officer—A. D. Nicholson, B.Ag.Sc.

At National Cattle Breeding Station, "Belmont", Rockhampton, Queensland—
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Senior Research Officer—H. G. Turner, B.Agr.Sc., M.A.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Senior Research Officer—A. B. Beck, M.Sc.

At Institute of Agriculture, University of Western Australia, Nedlands, Western Australia—
Senior Research Officer—E. Munch-Petersen, M.Sc., B.A., M.I.F.

At University of Adelaide, Adelaide, South Australia—
Research Officer—G. W. Grigg, M.Sc., Ph.D.

6. Division of Biochemistry and General Nutrition.
(Head-quarters: University of Adelaide.)
Chief—H. R. Marston, F.R.S.
Technical Secretary—A. Packham, B.V.Sc., A.A.S.A.
Principal Research Officer—A. W. Peirce, D.Sc.
Principal Research Officer—D. S. Riceman, M.Sc., B.Ag.Sc., R.D.A.
Principal Research Officer—H. J. Lee, M.Sc.
Principal Research Officer—F. V. Gray, M.Sc.
Principal Research Officer—Miss M. C. Dawbarn, M.Sc.
Senior Research Officer—J. A. Mills, Ph.D., M.Sc.
Senior Research Officer—I. G. Jarrett, M.Sc.
Senior Research Officer—G. B. Jones, M.Sc.
Senior Research Officer—Miss S. H. Allen, B.Sc.
Senior Research Officer—A. F. Pilgrim, B.Sc.
Research Officer—L. J. Frahn, Ph.D., M.Sc.
Research Officer—B. J. Potter, M.Sc.
Research Officer—R. M. Smith, B.Sc.
Research Officer—R. A. Weller, B.Sc.
Research Officer—R. E. Kuchel, B.Sc., R.D.A.
Research Officer—Mrs. D. C. Roder, M.Sc.
Principal Technical Officer—D. W. Dewey.
Senior Technical Officer—R. H. Jones, R.D.A.
Technical Officer—V. A. Stephen.
Technical Officer—J. O. Wilson (part-time).
Technical Officer—O. H. Filsell, B.Sc.
Technical Officer—A. C. Blaskett, B.Sc.
Technical Officer—B. F. Good, B.Sc.
Librarian—Miss J. W. White, B.A.

7. Division of Building Research.
(Head-quarters: Graham-road, Highett, Victoria.)

Administration—
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Technical Secretary—J. R. Barned, B.Sc.
Research Officer—I. C. H. Croll, B.Sc.
Sectional Draughtsman—W. Maier, Dip.Ing.

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Senior Research Officer—R. C. McTaggart, B.Sc.
Senior Technical Officer—E. M. Coulter, M.Agr.Sc.
Librarian—Mrs. S. A. Curwen.

Concrete and Testing Laboratory—
Senior Research Officer—F. A. Blakey, B.E., Ph.D.
Principal Technical Officer—W. H. Taylor, M.C.E.
Senior Technical Officer—R. E. Lewis, B.Sc.(Hons.).
Technical Officer—E. N. Mattison.
Technical Officer—I. Leber, Dip.Ing.
Technical Officer—F. D. Beresford, F.M.T.C.
Technical Officer—J. J. Russell, B.Sc.

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Senior Research Officer—H. V. Hueber, Dr. Phil.
Senior Research Officer—W. F. Cole, M.Sc., Ph.D.
Senior Research Officer—R. D. Hill, B.Sc., B.Com.
Research Officer—Mrs. T. Demediuk, Dr. Phil.
Research Officer—Miss A. A. Milne, B.Sc., Ph.D.
Technical Officer—Miss M. E. Neilson, B.Sc.
Technical Officer—A. E. Holland, A.M.T.C.
Technical Officer—C. L. Carrel, B.Sc.
Technical Officer—D. N. Crook, A.Sw.T.C.

Surfacing Materials Investigations—
Senior Research Officer—E. H. Waters, M.Sc.
Research Officer—J. E. Bright, B.Sc.
Technical Officer—D. A. Powell, B.Sc.
Technical Officer—I. D. McLachlan, A.S.M.B.

Acoustics and Thermal Investigations—
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Senior Research Officer—W. K. R. Lippert, Dr. Phil.
Senior Research Officer—A. F. B. Nickson, M.Sc.
Research Officer—T. S. Holden, B.Sc.
Technical Officer—A. W. Wilson, B.Sc.
Technical Officer—P. I ubout, B.Sc.
Technical Officer—R. M. Taylor, B.Sc.

Organic Materials Investigations—
Research Officer—E. R. Ballantyne, B.Sc.
Trainee Research Officer—K. G. Martin, B.Sc. (abroad).
Technical Officer—J. W. Spencer, B.Sc.
Technical Officer—N. G. Brown, A.M.T.C.
Technical Officer—B. L. Reidy, A.M.T.C.

8. Canberra Laboratories, Administrative Office.
(The services of this office are common to the Divisions of Plant Industry and Entomology, and to the Land Research and Regional Survey Section.)
Chief Clerk—K. J. Prowse.
Deputy Chief Clerk—D. Ranyard.
Accountant—L. J. Peres, B.Ec.

9. Central Experimental Workshops.
(Head-quarters: Explosives Factory, Maribyrnong, Victoria.)
Electrical and Mechanical Engineer—R. N. Morse, B.Sc., B.E.
Engineer-in-charge—F. G. Hogg, B.E.
Plant Engineer—K. A. Robeson, B.Mech.E.
Senior Research Officer—J. Kowalczewski, Dipl.Ing.
Research Officer—I. P. Arthur, B.Mech.E. (on leave).
Research Officer—M. G. Kovarik, Dipl.Ing.

Senior Technical Officer—D. W. Cunliffe, F.M.T.C.
Technical Officer—J. T. Czarnecki, Dipl.Ing.
Chief Draughtsman—G. T. Stephens, Dip.Mech.Eng., Dip.Elec.Eng.
Sectional Draughtsman—W. R. Read.
Draughtsman, Grade II.—J. R. Mitchell, Dip.Mech. Eng., Dip.Elec.Eng.
Draughtsman, Grade II.—H. Smith, A.R.M.T.C.
Draughtsman, Grade II.—E. T. Davey.
Sectional Draughtsman—C. M. Williamson (at Sydney).

10. Coal Research Section.

(Head-quarters: Delhi-road, North Ryde, (New South Wales.)

Officer-in-charge—H. R. Brown, B.Sc.(Eng.).
Principal Research Officer—N. Y. Kirov, M.Sc.
Senior Research Officer—J. D. Brooks, B.Sc.
Senior Research Officer—P. L. Waters, B.Sc., Ph.D., D.I.C.
Senior Research Officer—E. J. Greenhow, B.Sc., Ph.D.
Senior Research Officer—A. Jowett, B.Sc., Ph.D.
Research Officer—B. E. Balme, B.Sc.(Hons.).
Research Officer—R. A. Durie, M.Sc., Ph.D., D.I.C.
Research Officer—M. Kossenberg, Ph.D.
Research Officer—G. H. Taylor, M.Sc., Ph.D. (on overseas studentship).
Senior Technical Officer—M. S. Burns, A.M.I.F.
Senior Technical Officer—R. H. Jones, B.Sc.(Hons.).
Technical Officer—R. P. McDonald, M.Sc.
Technical Officer—J. W. Smith, A.R.I.C., A.M.I.F.
Technical Officer—C. K. Ferguson, B.Sc.(Min.Eng.), Dipl.R.T.C.
Technical Officer—J. P. F. Hennelly, B.Sc.
Technical Officer—G. à Donau-Szpindler, Dipl.Ing., D.I.C.
Technical Officer—J. W. Sweeting, B.Sc.
Technical Officer—T. P. Maher, B.Sc.(Hons.).
Technical Officer—D. H. Phillips, A.S.T.C.
Technical Officer—A. J. Ryan, B.Sc.
Technical Officer—A. Watts, A.S.M.B.
Technical Officer—H. N. S. Schafer, B.Sc.(Hons.)
Technical Officer—J. Szewczyk, M.Phys., Dipl.Ing. Chem.
Technical Officer—P. R. C. Goard, B.Sc.
Technical Officer—J. N. Stephens, M.A.
Technical Officer—W. O. Stacy, B.Sc.
Technical Officer—Miss R. G. Loomes, A.S.T.C.
Technical Officer—Miss A. McI. Murray, B.Sc.
Librarian—Miss R. Souhami, B.Sc.

11. Dairy Research Section.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—G. Loftus Hills, B.Agr.Sc.
Technical Secretary—A. K. Klingender, B.Sc.
Principal Research Officer—N. King, M.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Senior Research Officer—K. Kumetat, Ph.D.
Senior Research Officer—J. Conochie, B.Sc.(Agric.).
Senior Research Officer—J. Czulak, B.Sc.(Agric.), Dip.Bact.
Research Officer—A. J. Lawrence, B.Sc.
Research Officer—D. A. Forss, M.Sc.
Research Officer—J. W. Lee, B.Sc.(Hons.) (on study leave).
Senior Technical Officer—Miss R. M. P. Keogh, M.Sc.
Technical Officer—R. Beeby, A.M.T.C.

12. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—F. J. Lehany, M.Sc.
Technical Secretary—R. C. Richardson, B.E.
Principal Research Officer—W. K. Clothier, B.Sc., M.E.
Principal Research Officer—A. M. Thompson, B.Sc. (Hons.).
Principal Research Officer—R. J. Meakins, B.Sc. (Hons.), Ph.D., D.I.C.
Principal Research Officer—B. V. Hamon, B.Sc. (Hons.), B.E.
Principal Research Officer—D. L. Hollway, B.E.E., M.Eng.Sc., D.Sc.(Eng.).
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—J. S. Dryden, M.Sc., Ph.D., D.I.C.
Research Officer—J. J. O'Dwyer, B.Sc., B.E., Ph.D.
Research Officer—T. M. Palmer, Dipl.F.H.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—D. L. H. Gibbings, B.E., B.Sc., Ph.D.
Research Officer—D. W. Posener, M.Sc., Ph.D.
Research Officer—H. K. Welsh, M.Sc.
Research Officer—G. J. Johnson, B.Sc.(Hons.).
Research Officer—D. G. Lampard, M.Sc., Ph.D.
Research Officer—W. E. Smith, B.Sc.(Hons.) (studentship abroad).
Research Officer—P. G. Harper, B.Sc., Ph.D.
Principal Technical Officer—L. Medina, Dipl.Ing.
Senior Technical Officer—L. M. Mandl, Dipl.Ing., A.S.T.C.
Senior Technical Officer—F. C. Brown, A.S.T.C.
Senior Technical Officer—H. A. Smith, A.S.T.C.
Technical Officer—R. W. Archer, A.S.T.C.
Technical Officer—E. Cowcher, B.A., A.S.T.C. (on leave).
Technical Officer—H. C. Collins, A.S.T.C.
Technical Officer—J. M. Melano, A.S.T.C.
Technical Officer—M. C. McGregor, A.S.T.C.
Technical Officer—K. M. Goodson, B.Sc.
Technical Officer—F. C. Hawes, A.S.T.C.
Technical Officer—J. S. Cook, B.Sc.
Technical Officer—R. E. Holmes, A.S.T.C.
Technical Officer—R. P. Hoffman, A.S.T.C.
Technical Officer—D. A. Mustard, B.Sc.

13. Division of Entomology.

(Head-quarters: Canberra, Australian Capital Territory.)

At Canberra—

Administration—
Chief—A. J. Nicholson, D.Sc. (abroad).
Assistant Chief—D. F. Waterhouse, D.Sc.
Technical Secretary—K. L. Taylor, B.Sc.Agr.

Population Dynamics—
Chief of Division—A. J. Nicholson, D.Sc. (abroad).
Senior Technical Officer—A. T. Mills.

Field Population Studies—
Principal Research Officer—L. R. Clark, M.Sc.
Technical Officer—A. Magassy, Dr.Agr.Sc. (Budapest).

Termite Investigations—
Principal Research Officer—F. J. Gay, B.Sc. (Hons.), D.I.C.

Locust and Grasshopper Investigations—
Principal Research Officer—K. H. L. Key, D.Sc.
Technical Officer—L. J. Chinnick, R.D.A.

Miscellaneous Grasshopper Investigations—
Research Officer—D. P. Clark, B.Sc.(Hons.)

Biological Control—
Principal Research Officer—F. Wilson.
Research Officer—G. F. Bornemissza, Ph.D.
Research Officer—Miss M. Fielding, B.Sc.(Hons.), Ph.D.

Insecticide Investigations—
Senior Research Officer—R. W. Kerr, B.Sc.

Physiology and Toxicology—
Assistant Chief—D. F. Waterhouse, D.Sc.
Senior Research Officer—D. Gilmour, M.Sc.
Senior Research Officer—R. H. Hackman, M.Sc. Ph.D.

Research Officer—R. F. Powning, A.S.T.C., M.Sc.
Research Officer—L. B. Barton-Browne, B.Sc. (Hons.), Ph.D.
Research Officer—A. R. Gilby, M.Sc.
Research Officer—L. G. Webber, M.Sc.
Senior Technical Officer—H. Irzykiewicz.
Technical Officer—Mrs. M. M. Goldberg, B.Sc.

Taxonomy of Diptera—
Senior Research Officer—S. J. Paramonov, D.Sc.

Museum—
Research Officer—T. G. Campbell.

Virus Vestor Investigations—
Principal Research Officer—M. F. Day, B.Sc. (Hons.), Ph.D.
Research Officer—T. D. C. Grace, B.Sc.(Hons.)
Technical Officer—N. E. Grylls, D.D.A.

Cockchafer Investigations—
Senior Research Officer—P. B. Carne, B.Agr.Sc., Ph.D.

Ant Investigations—
Senior Research Officer—T. Greaves.

Pasture Caterpillar Investigations—
Senior Research Officer—I. F. B. Common, M.A., M.Agr.Sc.

Stored Products Pests Investigations—
Senior Research Officer—S. W. Bailey, B.Sc., A.R.C.S.

Potato Moth and Taxonomy of Hymenoptera—
Senior Research Officer—E. F. Riek, M.Sc. (abroad).

At Yeerongpilly, Queensland—

Cattle Tick Investigations—
Principal Research Officer—K. R. Norris, M.Sc.
Senior Research Officer—P. R. Wilkinson, M.A.
Senior Research Officer—W. J. Roulston, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.
Technical Officer—H. Schnitzerling, Dip.Ind. Chem.
Technical Officer—B. F. Stone, Dip.Ind.Chem.

At Nedlands, Western Australia—

Earth Mite and Lucerne Flea Investigations—
Senior Research Officer—M. M. H. Wallace, B.Sc.(Hons.).
Technical Officer—J. A. Mahon, Dip.D.Sci.

At Sydney—

Biological Control—
Senior Research Officer—G. J. Snowball, B.Sc. (Hons.).

14. Division of Fisheries.

(Head-quarters: Cronulla, New South Wales.)

At Cronulla—
Chief—Vacant.
Acting Chief—M. Blackburn, D.Sc.
Technical Secretary—Mrs. L. M. Willings, B.A.
Research Fellow—L. G. M. Baas Becking, Ph.D., D.Sc.
Principal Research Officer—D. J. Rochford, B.Sc. (Hons.).
Principal Research Officer—E. J. Ferguson Wood, B.A., M.Sc.
Senior Research Officer—I. S. R. Munro, M.Sc.
Senior Research Officer—J. M. Thomson. M.Sc.
Research Officer—R. S. Spencer, B.Sc.(Hons.).
Research Officer—T. R. Cowper, B.Sc.(Hons.).
Research Officer—W. Dall, M.Sc.
Research Officer—G. S. Grace, B.Sc.
Research Officer—J. P. Robins, B.Sc.
Research Officer—R. J. MacIntyre, M.Sc.
Technical Officer—D. J. Dunstan. B.Sc.
Technical Officer—H. R. Jitts, B.Sc.
Technical Officer—N. L. Brown, A.S.T.C.
Technical Officer—P. S. Davis, A.S.T.C.
Technical Officer—C. Walker, M.Pharm.
Technical Officer—I. R. Kaplan, M.Sc.
Technical Officer—Miss B. B. Dew, B.A.

At Melbourne—
Technical Officer—P. E. Gartner, B.Sc.

At Lakes Entrance, Victoria—
Research Officer, D. E. Kurth, M.Sc.

At Perth, Western Australia—
Senior Research Officer—K. Sheard, D.Sc.
Research Officer—W. B. Malcolm, B.Sc.
Research Officer—R. G. Chittleborough, M.Sc.
Research Officer—R. W. George, B.Sc.(Hons.).
Technical Officer—A. Middleton, B.Sc., Dip.Chem.

At Hobart—
Senior Research Officer—A. G. Nicholls, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. M. Olsen, M.Sc.
Research Officer—A. H. Weatherley, B.Sc.

At Thursday Island, Queensland—
Research Officer—J. S. Hynd, B.Sc.
Technical Officer—D. J. Tranter, B.Sc.

15. 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.
Technical Officer—Miss E. M. Christie, B.Sc.
Senior Librarian—Miss B. Johnston, B.Sc.

Physics and Transport Section—
Senior 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.
Research Officer—H. L. Evans, M.Sc.
Technical Officer—Mrs. J. A. Anet, B.Sc.

Microbiology Section—
Principal Research Officer—W. J. Scott, B.Agr.Sc.
Senior Research Officer—W. G. Murrell, B.Sc.Agr., D.Phil.
Research Officer—J. H. B. Christian, B.Sc.Agr. (Hons.), (overseas).
Research Officer—R. D. H. Leach, M.Sc., D.Phil.
Senior Technical Officer—D. F. Ohye, D.I.C.
Technical Officer—Miss B. J. Marshall, A.S.T.C.

Biochemistry Investigations—
Principal Research Officer—F. E. Huelin, B.Sc. (Hons.), Ph.D.
Research Officer—J. B. Davenport, M.Sc.
Technical Officer—B. H. Kennett, A.S.T.C.

Organic Chemistry Investigations—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Research Officer—E. F. L. J. Anet, M.Sc., Ph.D.

Fruit and Vegetable Storage Section—
Senior Research Officer—E. G. Hall, B.Sc.Agr. (Hons.).
Research Officer—Miss J. M. Bain, M.Sc.
Technical Officer—T. J. Riley, H.D.A.

Canning and Fruit Products Section—
Principal Research Officer—L. J. Lynch, B.Agr.Sc. (Hons.).
Principal Research Officer—J. F. Kefford, M.Sc.
Senior Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—B. V. Chandler, B.Sc.
Research Officer—E. G. Davis, B.Sc.(Hons.).
Research Officer—P. W. Board, B.Sc.
Technical Officer—T. A. Meyer, Dipl.Agr.

Dried Foods Section—
Research Officer—D. McG. McBean, B.Sc.
Technical Officer—A. A. Johnson, A.S.T.C.

Fish Preservation Investigations—
Principal Research Officer—W. A. Empey, B.V.Sc.
Technical Officer—W. A. Montgomery, A.S.T.C.

Egg Investigations—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Officer—F. S. Shenstone, A.S.T.C.

Freezing of Fruit and Vegetables—
Research Officer—I. J. Tinsley, B.Sc.(Hons.), M.S. (overseas).
Research Officer—J. H. Scheltema, M.Sc.

At Auburn, New South Wales.—
Meat Dehydration Investigations—
Senior Research Officer—A. R. Prater, B.Sc.Agr.
Technical Officer—F. J. Gardner, B.Sc.Agr.

At Botany School, University of Sydney.—
Plant Physiology Investigations—
Senior Principal Research Officer—R. N. Robertson, B.Sc.(Hons.), Ph.D.
Senior Research Officer—H. S. McKee, B.A., D.Phil. (overseas).
Senior Research Officer—J. F. Turner, M.Sc., Ph.D.
Research Officer—S. I. Honda, M.Sc., Ph.D.
Research Officer—Mrs. D. H. Turner, M.Sc., Ph.D.
Research Officer—A. B. Hope, B.Sc.(Hons.), Ph.D.
Technical Officer—M. D. Hatch, B.Sc.(Hons.).
Technical Officer—N. F. B. Tobin, B.Sc.
Technical Officer—J. Smydzuk, Ing. of Ch.

At Botany School, University of Melbourne—
Plant Physiology Investigations—
Research Officer—K. S. Rowan, M.Sc.

At Biochemistry School, University of Sydney—
Physical Chemistry Section—
Senior Research Officer—H. A. McKenzie, M.Sc.
Research Officer—J. J. Macfarlane, M.Sc.
Technical Officer—M. B. Smith, A.S.A.S.M.

At Tasmanian Regional Laboratory, Hobart, Tasmania—
Canning and Fruit Products—
Technical Officer—R. A. Gallop, A.S.T.C.
Fish Preservation Investigations—
Technical Officer—K. W. Anderson, A.M.T.C.

At Cannon Hill, Queensland—
Meat Investigations—
Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr. Ing.
Research Officer—A. D. Brown, M.Sc.
Research Officer—P. R. McCarthy, B.Sc. App.
Research Officer—H. L. Webster, B.Sc.(Hons.), Ph.D.
Technical Officer—N. T. Russell, D.I.C.
Technical Officer—M. F. Meaney, B.Sc.(Hons.).
Technical Officer—P. E. Bouton, B.Sc.

With United Kingdom Ministry of Food—
Senior Research Officer—N. E. Holmes, B.E.E., M.Mech.E. (seconded).

With Commonwealth Department of Commerce and Agriculture, Sydney—
Research Officer—J. Shipton, B.Sc.Agr. (seconded).

16. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant Chief—C. S. Elliott, B.Sc.
Assistant Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Research Officer—A. P. Wymond, M.Sc.
Senior Librarian—Miss M. I. Hulme.
Librarian—Miss A. Forbes.
Principal Technical Officer—L. Santer, M.Mech.E., Dip.Eng.
Technical Officer—P. J. Moglia, Dip.Mech.Eng.

Wood and Fibre Structure Section—
Chief Research Officer-in-charge—H. E. Dadswell, D.Sc.
Principal Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—W. E. Hillis, M.Sc., A.G.Inst.Tech.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Senior Research Officer—I. V. Newman, M.Sc., Ph.D.
Technical Officer—Miss M. F. Day, B.Sc. (on extended leave).
Technical Officer—C. F. James, B.Sc.
Technical Officer—J. W. P. Nicholls, B.Sc.
Technical Officer—Mrs. E. Scaife, B.Sc.

Wood Chemistry Section—
Senior Principal Research Officer—W. E. Cohen, D.Sc.
Principal Research Officer—D. E. Bland, M.Sc.
Senior Research Officer—H. G. Higgins, B.Sc. (Hons.).
Senior Research Officer—R. C. McK. Stewart, B.Sc.
Senior Research Officer—A. J. Watson, A.M.T.C.
Research Officer—Miss J. F. Hobden, B.Sc. (Hons.).
Research Officer—A. von Koeppen, Dr. Ing.
Technical Officer—Mrs. E. F. Frydman, B.Sc.
Technical Officer—Miss V. Goldsmith, A.M.T.C. (on leave).
Technical Officer—A. W. McKenzie, A.M.T.C.
Technical Officer—J. A. McPherson, B.Sc. (on leave).
Technical Officer—Miss G. Schwerin, B.Sc.
Technical Officer—Miss C. Stamp, B.Sc.

Timber Physics Section—
Principal Research Officer-in-charge—R. S. T. Kingston, B.Sc., B.E.
Senior Research Officer—G. N. Christensen, M.Sc., Ph.D.
Senior Research Officer—L. N. Clarke, M.Mech.E., B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, B.Sc.
Technical Officer—L. D. Armstrong, A.M.T.C.
Technical Officer—N. C. Edwards, A.S.M.B.
Technical Officer—P. U. A. Grossman, Ph.A.Mr.

Timber Mechanics Section—
Principal Research Officer-in-charge—J. D. Boyd, M.C.E.
Senior Research Officer—N. H. Kloot, M.Sc.
Senior Research Officer—R. G. Pearson, B.A., B.C.E.
Senior Technical Officer—J. J. Mack, A.M.T.C.
Technical Officer—K. B. Schuster, A.M.T.C.
Technical Officer—Miss A. Ryan, A.M.T.C.

Timber Seasoning Section—
Senior Principal Research Officer-in-charge—G. W. Wright, M.E.
Senior Research Officer—J. W. Gottstein, B.Sc.
Research Officer—W. G. Kauman, B.Sc., A.M.T.C.
Senior Technical Officer—L. J. Brennan.
Technical Officer—F. J. Christensen, A.M.T.C.

Timber Preservation Section—
Principal Research Officer-in-charge—N. Tamblyn, M.Sc. (Agric.).
Senior Research Officer—E. W. B. Da Costa, M.Agr.Sc.

Senior Research Officer—E. L. Ellwood, M.Sc. (For.), Ph.D.
Principal Technical Officer—F. A. Dale, Dip. Mech.Eng.
Senior Technical Officer—J. Beesley, Dip.For., M.Sc.(For.).
Senior Technical Officer—N. E. M. Walters, B.Sc.
Technical Officer—T. E. H. Aplin, B.Sc.
Technical Officer—D. F. McCarthy, A.M.T.C.

Timber Utilization Section—
Senior Principal Research Officer-in-charge—R. F. Turnbull, B.E.(Hons.).
Research Officer—W. M. McKenzie, B.Sc. (For.).
Research Officer—K. F. Plomley, B.Sc.Agr.
Senior Technical Officer—R. L. Cowling, Dip. Mech.Eng., Dip.E.E.
Technical Officer—D. S. Jones, B.C.E. (training overseas).

17. Division of Industrial Chemistry.

(Head-quarters: Lorimer-street, Fishermens' Bend, Victoria.)

Administration—
Chief—I. W. Wark, D.Sc., Ph.D.
Divisional Secretary—L. Lewis, B.Met.E.

Minerals Utilization Section—
Senior Principal Research Officer—R. G. Thomas, B.Sc.
Principal Research Officer—T. R. Scott, D.Sc., B.Ed.
Principal Research Officer—A. Walkley, B.A., D.Sc., Ph.D.
Principal Research Officer—A. W. Wylie, M.Sc., Ph.D.
Senior Research Officer—R. C. Croft, M.Sc.
Senior Research Officer—F. K. McTaggart, M.Sc.
Senior Research Officer—I. E. Newnham, M.Sc.
Senior Research Officer—A. D. Wadsley, M.Sc.
Senior Research Officer—I. H. Warren, B.Sc. (Hons.).
Research Officer—P. M. J. Gray, B.Sc.(Hons.), A.R.S.M.
Research Officer—D. F. A. Koch, B.Sc.(Hons.).
Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—D. E. Scaife, B.Sc.(Hons.).
Research Officer—A. G. Turnbull, B.Chem.Eng.
Senior Technical Officer—H. R. Skewes, A.A.C.I.
Technical Officer—Miss I. J. Bear, A.M.T.C.
Technical Officer—H. W. Fander, B.Sc. (Special).
Technical Officer—Miss E. E. Rutherford, B.Sc.

Cement and Ceramics Section—
Principal Research Officer—A. J. Gaskin, M.Sc.
Principal Research Officer—H. E. Vivian, B.Sc. Agr.
Principal Research Officer—G. F. Walker, B.Sc. (Hons.), Ph.D.
Principal Research Officer—W. O. Williamson, B.Sc., Ph.D.
Senior Research Officer—S. M. Brisbane, B.A., B.Sc., A.M.T.C.
Senior Research Officer—H. Ellerton (at Bonython Research Laboratory, School of Mines, Adelaide.)
Senior Research Officer—L. S. Williams, D.Phil., B.E.
Research Officer—K. M. Alexander, M.Sc., Ph.D.
Research Officer—G. M. Bruere, M.Sc.
Research Officer—J. H. Taplin, B.Sc.(Hons.).
Senior Technical Officer—C. E. S. Davis, B.Sc. (Hons.).
Senior Technical Officer—K. Grant, B.Sc. (Hons.)
Senior Technical Officer—J. D. Wolfe.
Technical Officer—P. J. Darragh, B.Sc.
Technical Officer—R. R. Hughan.
Technical Officer—Mrs. M. Lawrence, B.Sc.
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. Wardlaw, B.Sc.
Technical Officer—J. H. Weymouth, B.Sc.

Foundry Sands Section—
Senior Research Officer—H. A. Stephens, B.Sc.
Technical Officer—P. W. Goad, A.M.T.C. (on study leave).
Technical Officer—A. N. Waterworth, A.H.T.C.

Chemical Physics Section—
Chief Research Officer—A. L. G. Rees, D.Sc., Ph.D.
Senior Principal Research Officer—A. Walsh, M.Sc.Tech.
Principal Research Officer—J. L. Farrant, M.Sc.
Principal Research Officer—A. McL. Mathieson, B.Sc., Ph.D.
Principal Research Officer—D. A. Davies, B.Sc.
Senior Research Officer—J. M. Cowley, M.Sc., Ph.D.
Senior Research Officer—J. D. Morrison, B.Sc., Ph.D.
Senior Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Senior Research Officer—J. B. Willis, M.Sc., Ph.D.
Senior Research Officer—G. R. Hereus, M.Sc., D.Phil.
Senior Research Officer—J. Fridrichsons, M.Sc.
Research Officer—A. J. Hodge, B.Sc.(Hons.), Ph.D.
Research Officer—B. Dawson, M.Sc., Ph.D.
Research Officer—A. F. Moodie, B.Sc.(Hons.).
Research Officer—C. K. Coogan, M.Sc., Ph.D.
Research Officer—A. C. Hurley, M.A., B.Sc., Ph.D. (on leave of absence).
Research Officer—J. P. Shelton, M.Sc., A.B.S.M. (seconded to A.S.L.O., London).
Research Officer—F. H. Dorman, M.A., M.Sc., Ph.D.
Research Officer—C. Billington, B.A.
Research Officer—J. O. Cope, M.Sc.
Research Officer—J. C. Rivière, M.Sc., Ph.D.
Research Officer—A. F. Beecham, B.Sc.(Hons.).
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia).
Research Officer—P. Goodman, M.Sc.
Research Officer—N. S. Ham, M.Sc. (on study leave).
Research Officer—Mrs. Lois Mathieson, B.Sc. (Hons.).
Research Officer—Miss Barbara J. Russell, M.Sc.
Research Officer—W. C. T. Dowell, M.Sc.
Technical Officer—E. Chakanovskis, Dipl.Eng.
Technical Officer—D. L. Swingler, B.Sc.

Physical Chemistry Section—
Chief Research Officer—K. L. Sutherland, D.Sc., Ph.D.
Principal Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Senior Research Officer—J. A. Barker, B.A. (Hons.), B.Sc.
Senior Research Officer—I. Brown, B.Sc.(Hons.).
Senior Research Officer—W. E. Ewers, M.Sc.
Senior Research Officer—V. A. Garten, D.Sc.
Senior Research Officer—W. W. Mansfield, B.Sc. (Hons.).
Senior Research Officer—E. A. Swinton, B.Sc. (Hons.).
Senior Research Officer—D. E. Weiss, B.Sc.
Senior Research Officer—M. E. Winfield, M.Sc., Ph.D.
Research Officer—H. G. David, B.Sc. (at Department of Chemical Engineering, University of Sydney).

Research Officer—A. Ewald, B.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Research Officer—T. Gabor, B.Sc.(Hons.).
Research Officer—W. N. K. King, B.Sc.
Research Officer—E. P. Purser, B.Sc.(Hons.).
Senior Technical Officer—L. F. Evans, A.S.M.B.
Technical Officer—K. Eppinger, B.Sc.
Technical Officer—W. Fock, B.Sc.
Technical Officer—M. Linton, B.Sc.
Technical Officer—R. McNeill, A.Sw.T.C.
Technical Officer—F. Meadows, B.Sc.
Technical Officer—M. Ross, Ing.
Technical Officer—F. Smith, B.Sc.

Organic Chemistry Section—
Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Senior Principal Research Officer—J. R. Price, D.Sc., D.Phil.
Principal Research Officer—W. Zimmermann, D.Ing.
Senior Research Officer—R. B. Bradbury, B.Sc., Ph.D.
Senior Research Officer—C. C. J. Culvenor, Ph.D., D.Phil.
Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D.
Senior Research Officer—K. E. Murray, B.Sc. (Hons.).
Research Officer—C. S. Barnes, M.Sc., Ph.D.
Research Officer—W. D. Crow, M.Sc., Ph.D.
Research Officer—L. K. Dalton, A.S.T.C.
Research Officer—E. Gellert, Ph.D.
Research Officer—N. C. Hancox, M.Sc.
Research Officer—J. A. Lamberton, B.Sc.(Hons.), Ph.D.
Research Officer—W. Segal, M.Sc., Ph.D.
Research Officer—P. C. Wailes, M.Sc., Ph.D.
Technical Officer—Mrs. Y. Greet, B.Sc.
Technical Officer—P. M. Hunter, A.M.T.C.
Technical Officer—M. Michael, M.Sc. (on study leave).
Technical Officer—A. Palmer, A.M.T.C.
Technical Officer—A. H. Redcliffe, Dip.Anal.Chem. M.U.
Technical Officer—Mrs. I. Salivin, A.M.T.C.
Technical Officer—L. W. Smith, B.Sc.
Technical Officer—A. Z. Szumer, A.M.T.C. (on study leave).

Chemical Engineering Section—
Principal Research Officer—R. W. Uric, B.Sc., S.M.
Senior Research Officer—T. J. Birch, B.Sc.
Senior Research Officer—J. D. Blackwood, M.Sc., Ph.D.
Research Officer—K. Hall, M.Sc.
Research Officer—O. G. Ingles, B.A., M.Sc.
Research Officer—P. Terry, B.Sc.(Hons.), M.S. (Chem.Eng.).
Research Officer—A. B. Whitehead, B.Sc.(Hons.).
Senior Technical Officer—D. H. Trethewey, A.M.T.C.
Senior Technical Officer—B. W. Wilson, M.Sc.
Technical Officer—P. Casamento, D.Chem.
Technical Officer—A. Dielenberg, Dip.Ing.
Technical Officer—F. McGrory, B.Sc.
Technical Officer—C. W. Thomas, B.Sc.

At Division of Electrotechnology, Sydney—
Research Officer—H. K. Welsh, M.Sc. (seconded).

Engineering Services—
Senior Technical Officer—J. B. Ross, B.Sc., A.M.T.C.
Sectional Draughtsman—C. Simpson.

Library—
Librarian—Miss B. M. Brown, B.Sc.

18. Irrigation Research Stations.

(Head-quarters: Merbein, Victoria.)

Senior Officer-in-charge—F. Penman, M.Sc.

At Commonwealth Research Station, Merbein (Murray Irrigation Areas)—
Officer-in-charge—F. Penman, M.Sc.
Principal Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Senior Research Officer—R. J. L. Martin, M.Sc., Ph.D.
Research Officer—W. J. Webster, B.Sc.
Research Officer—A. J. Antcliff, B.Sc.(Hons.).
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. McE. Alexander, B.Sc.
Research Officer—M. Maasland, Ir.Agr., M.Sc.
Research Officer—J. V. Seekamp, B.Agr.Sc. (part-time).
Senior Technical Officer—J. E. Giles.
Technical Officer—G. L. Stott, A.S.T.C.
Technical Officer—S. A. Giddings, B.Sc.
Technical Officer—P. May, Ing.Agr.

At Irrigation Research Station, Griffith (Murrumbidgee Irrigation Areas)—
Officer-in-charge—E. S. West, B.Sc., M.S.
Research Officer—C. T. Gates, B.Sc.Agr.(Hons.).
Research Officer—T. Talsma, Ir.Agr.
Research Officer—D. Bouma, Ir.Agr.
Research Officer—H. Groenewegen, Ir.Agr.
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.(Hons.), Ph.D.

19. Land Research and Regional Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)

Administration—
Officer-in-charge—C. S. Christian, B.Agr.Sc., M.S.
Technical Secretary—Miss M. Mills, B.Sc.(Hons.).

Regional Surveys—
Senior Research Officer—G. A. Stewart, M.Agr.Sc.

Australian Mainland Survey, Canberra—
Senior Research Officer—R. A. Perry, B.Sc. (Hons.).
Research Officer—N. H. Speck, M.Sc.
Research Officer—J. R. Sleeman, B.Agr.Sc. (seconded from Division of Soils).
Research Officer—C. R. Twidale, M.Sc.
Technical Officer—M. Lazarides, Q.D.A.

Papua-New Guinea Survey, Canberra—
Research Officer—H. A. Haantjens, Ing.Agr.
Research Officer—R. D. Hoogland, D.Sc.
Research Officer—B. W. Taylor, B.Sc.
Research Officer—E. Reiner, Dr.rer.nat.
Technical Officer—J. Saunders, B.Sc.Agr.

Agricultural Research—
Principal Research Officer—E. Phillis, Ph.D., D.Sc.

At Katherine Research Station, Northern Territory—
Research Officer—W. Arndt, B.Agr.Sc.
Research Officer—F. H. Kleinschmidt, B.Agr.Sc.
Research Officer—R. Wetselaar, Ing.Agr.
Technical Officer—L. J. Phillips, Q.D.D.M.
Technical Officer—W. R. Stern, B.Sc.Agr.

At Kimberley Research Station, Western Australia—
Research Officer—L. C. Lee, B.Agr.Sc.
Technical Officer—E. C. B. Langfield.
Technical Officer—A. L. Chapman, B.Agr.Sc.

Climatology, Canberra—
Research Officer—R. O. Slatyer, M.Sc.(Agric.).
Research Officer—J. L. Frith, B.Sc.(Agric.) (Hons.).
Research Officer—J. C. Turner, B.Sc.Agr. (Hons.).

Arid Zone, Alice Springs—
Technical Officer—R. E. Winkworth, B.Sc.(Hons.).

20. Mathematical Instruments Section.

(Head-quarters: Department of Electrical Engineering, University of Sydney.)

Officer-in-charge—Professor D. M. Myers, B.Sc., D.Se.Eng.
Research Officer—M. W. Allen, B.E.

21. Division of Mathematical Statistics.

(Head-quarters: University of Adelaide.)

At Head-quarters, Adelaide—
Chief—E. A. Cornish, B.Agr.Sc., D.Sc.
Senior Research Officer—A. T. James, M.Sc., Ph.D.
Research Officer—G. N. Wilkinson, B.Sc.(Hons.).
Technical Officer—A. M. W. Verhagen, Cand.Nat. Phil.(Utrecht), B.A.(Hons.)

At Division of Animal Health and Production, Sydney—
Principal Research Officer—Miss H. A. Newton Turner, B.Arch.
Research Officer—V. J. Bofinger, B.Sc.(Hons.), Dip.Ed.
Research Officer—Miss N. B. Hemingway, B.Sc.

At Division of Animal Health and Production, Prospect, New South Wales—
Research Officer—H. Weiler, Lic.ès. Sc.(Par.).

At Division of Building Research, Highett, Victoria—
Senior Research Officer—R. Birtwistle, B.Sc.
Technical Officer—G. A. Watterson, B.A.

At Coal Research Section, North Ryde, New South Wales—
Research Officer—A. G. Elliott, B.Sc.(Hons.).

At Division of Food Preservation and Transport, Homebush, New South Wales—
Senior Research Officer—G. G. Coote, B.A., B.Sc.

At Division of Forest Products, Melbourne—
Principal Research Officer—E. J. Williams, B.Com., D.Sc.
Research Officer—W. B. Hall, B.A.

At Division of Plant Industry, Canberra—
Senior Principal Research Officer—G. A. McIntyre, B.Sc.(Hons.), Dip.Ed.
Research Officer—M. L. Dudzinski, B.Sc., B.Ec. (Hons.).

At Division of Plant Industry, Brisbane—
Research Officer—K. P. Haydock, B.Sc.(Hons.).

At Regional Pastoral Laboratory, Armidale, New South Wales—
Research Officer—P. F. May, B.Sc.Agr.(Hons.).

At Western Australian Regional Laboratory, Perth—
Research Officer—N. S. Stenhouse, B.Sc.

22. Division of Meteorological Physics.

(Head-quarters: Station-street, Aspendale, Victoria.)

Chief—C. H. B. Priestley, M.A., Sc.D.
Senior Principal Research Officer—W. C. Swinbank, B.Sc.
Principal Research Officer—E. L. Deacon, B.Sc.
Principal Research Officer—F. A. Berson, Ph.D.
Senior Research Officer—R. J. Taylor, B.Sc.
Research Officer—I. C. McIlroy, B.Sc.
Research Officer—E. K. Webb, B.A., B.Sc.
Research Officer—A. J. Dyer, M.Sc., Ph.D.
Research Officer—F. K. Ball, B.Sc.(Hons.).
Research Officer—C. F. Barrett, M.Sc.
Research Officer—W. W. Moriarty, M.Sc.
Technical Officer—D. E. Angus, B.Sc.
Technical Officer—A. J. Troup, B.Sc.
Technical Officer—R. R. McGregor, Dip.App.Sc.
Technical Officer—Mrs. N. F. MacNally, B.Sc. (Special).

23. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—N. A. Esserman, B.Sc.
Technical Secretary—N. J. C. Peres, M.Sc.
Senior Principal Research Officer—C. A. Gladman, B.Sc., A.C.G.I.
Principal Research Officer—G. A. Bell, B.Sc.
Principal Research Officer—C. F. Bruce, M.Sc.
Senior Research Officer—H. J. Ritter, Dr.rer.nat.-math.
Senior Research Officer—J. A. Macinante, B.E., A.S.T.C.
Senior Research Officer—M. J. Puttock, B.Sc.(Eng.).
Senior Research Officer—H. A. Ross, A.S.T.C.
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—Miss P. M. Yelland.
Research Officer—Miss M. C. Dive, B.Sc.
Research Officer—Miss M. M. Douglas, B.Sc.
Research Officer—W. A. F. Cuninghame, B.E.
Research Officer—J. Waldersee, B.Sc.
Research Officer—I. F. Mayer, B.E., B.Sc.
Research Officer—B. S. Thornton, M.Sc.
Research Officer—E. G. Thwaite, B.Sc.
Principal Technical Officer—R. H. Furniss, A.S.T.C.
Senior Technical Officer—B. H. P. Cresswell, A.S.T.C.
Senior Technical Officer—R. Springer, Dr.Mach.Const. (Cologne).
Senior Technical Officer—R. J. Ellis, B.E.
Senior Technical Officer—A. Gibson, A.S.T.C.
Senior Technical Officer—D. H. Fox, A.M.I.E. (Aust.).
Technical Officer—G. W. Gore, B.E., A.S.T.C.
Technical Officer—P. J. Sim, B.E., B.Sc.
Technical Officer—L. Cridland, A.S.T.C.
Technical Officer—E. Grunwald.
Technical Officer—P. Albrecht, Dipl.Ing.
Technical Officer—S. A. Dunk, B.E., A.S.T.C.
Technical Officer—R. S. Fisher, A.M.T.C.

24. Mineragraphic Investigations.

(Head-quarters: University of Melbourne.)

Chief Research Officer—A. B. Edwards, D.Sc., Ph.D., D.I.C.
Senior Research Officer—G. Baker, M.Sc.
Research Officer—J. McAndrew, M.Sc., Ph.D.
Research Officer—R. J. P. Lyon, B.Sc.(Hons.), Ph.D.

25. 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, F.A.S.A., A.C.I.S., J.P.
Accountant—F. J. Whitty.

Library—
Senior Librarian—Miss M. McKechnie, B.A.
Librarian—Miss J. M. Cook, B.A.
Librarian—Miss P. M. Callaghan, B.Sc.
Librarian—Mrs. M. P. Fowler.
Librarian—Miss P. I. Ross, B.A.

Workshops—
Engineer-in-charge—J. Hanna.

Drawing Office—
Chief Draughtsman—J. Coles.
Sectional Draughtsman, Grade II.—I. A. Rey, A.M.I.E., I.E.E.(Eng.).
Draughtsman, Grade II.—R. Partridge.
Draughtsman, Grade II.—J. Weir.

26. Oenological Research.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Principal Research Officer—J. C. M. Fornachon, M.Sc., B.Ag.Sc.
Research Officer—B. C. Rankine, M.Sc.

27. Ore-dressing Investigations.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Associate Professor H. H. Dunkin, B.Met.E.
Principal 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.
Senior Technical Officer—F. D. Drews.
Technical Officer—W. J. Trahar, B.Sc.

28. Physical Metallurgy Section.

(Head-quarters: University of Melbourne.)

Officer-in-charge (honorary)—Professor J. Neill Greenwood, D.Sc., M.Met.E. (overseas).
Principal Research Officer—H. W. Worner, D.Sc., M.Sc. (seconded overseas).
Senior Research Officer—R. C. Gifkins, B.Sc.
Research Officer—D. R. Miller, M.Sc.
Research Officer—J. W. Suiter, M.Sc.
Senior Technical Officer—J. A. Corbett.

29. Division of Physics.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—
Chief—G. H. Briggs, D.Sc., Ph.D.
Technical Secretary—D. S. Woodward.

Heat—
Principal Research Officer—A. F. A. Harper, M.Sc.
Senior Research Officer—W. R. G. Kemp, B.Sc.
Senior Research Officer—R. G. Wylie, M.Sc., Ph.D.
Senior Research Officer—G. K. White, M.Sc., D.Phil.
Senior Research Officer—P. G. Klemens, M.Sc., D.Phil.
Research Officer—W. A. Caw, B.Sc.(Hons.).
Research Officer—Miss R. Scott, B.Sc. (on leave abroad).
Research Officer—J. Middlehurst, M.Sc. (on study leave abroad).
Research Officer—J. A. Rayne, B.Sc., B.E.
Research Officer—J. V. McAllan, B.Sc.(Hons.).
Technical Officer—Miss I. M. Beavis, B.Sc., Dip.Ed.
Technical Officer—T. P. Jones, B.Sc.
Technical Officer—Miss W. Wilmanska, Dipl. Phys.

Light—
Principal Research Officer—R. G. Giovanelli, D.Sc.
Senior Research Officer—W. H. Steel, B.A., B.Sc., Dr.èsSc.
Research Officer—W. R. Blevin, M.Sc., Dip.Ed.
Research Officer—Associate Professor G. H. Godfrey, M.A., B.Sc. (part-time).
Research Officer—C. E. Coulman, M.Sc.
Senior Technical Officer—K. A. Wright, B.Sc. (on leave abroad).
Technical Officer—W. J. Brown, A.S.T.C.
Technical Officer—N. A. Florescu, D.Phys.

Solar Physics—
Research Officer—J. T. Jefferies, M.A., B.Sc.
Research Officer—R. E. Loughhead, M.Sc.
Technical Officer—V. R. Burgess, A.S.T.C.

Electronics—
Research Officer—A. F. Young, M.Sc.

30. Plant Fibre 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—W. Shepherd, B.Sc., B.Agr.Sc.
Technical Officer—C. J. Brady, B.Sc.Agr.
Technical Officer—J. A. Milne, A.M.T.C.
Technical Officer—R. E. Spielrein, A.M.T.C.

31. Division of Plant Industry.

(Head-quarters: Canberra, Australian Capital Territory.)

Administration—
Chief—O.H. Frankel, D.Sc., D.Agr., F.R.S.
Associate Chief—J. Griffiths Davies, B.Sc., Ph.D.
Assistant Chief—R. M. Moore, M.Sc.Agr.
Technical Secretary—A. Shavitsky, B.Agr.Sc.
Assistant Technical Secretary—J. H. E. Mackay, B.Sc.Agr.
Divisional Engineer—G. L. Brown, B.Sc.(Eng.), A.C.G.I.

Group 1—Botany and Genetics—
Leader—O. H. Frankel, D.Sc., D.Agr., F.R.S.
Deputy Leader—C. Barnard, D.Sc.

Genetics and Cytology, Canberra—
Senior Research Fellow—M. J. D. White, D.Sc.
Principal Research Officer—F. H. W. Morley, B.V.Sc., Ph.D.
Principal Research Officer—B. Griffing, M.S., Ph.D.
Senior Research Officer—R. D. Brock, M.Sc.Agr., Ph.D.
Research Officer—D. C. Wark, M.Agr.Sc.
Research Officer—H. Daday, M.Sc.
Research Officer—C. I. Davern, B.Agr.Sc.
Research Officer—J. B. Langridge, M.Sc.
Research Officer—D. L. Hayman, B.Ag.Sc. (Hons.).
Technical Officer—Miss R. Stephens, B.Sc. (Hons.).
Technical Officer—J. W. Peak.

Structural Botany, Canberra—
Principal Research Officer—C. Barnard, D.Sc.

Herbarium, Canberra—
Senior Research Officer—Miss N. T. Burbidge, M.Sc.

Plant Introduction, Canberra—
Principal Research Officer—W. Hartley, B.A., Dip.Ag.
Research Officer—C. A. Neal-Smith, B.Ag.Sc., R.D.A.
Research Officer—H. J. Ketellapper, Ph.D., B.Sc.
Technical Officer—R. J. Williams, B.Sc.
Technical Officer—Miss D. E. Johns, B.Sc.

Plant Introduction, Western Australia—
Senior Research Officer—E. T. Bailey, B.Sc.
Technical Officer—N. B. Gayfer, D.D.A.

Microbiology, Canberra—
Senior Research Fellow—K. O. Muller, D.Phil.

Senior Research Fellow—P. S. Nutman, B.Sc., Ph.D.
Principal Research Officer—H. R. Angell, O.B.E., Ph.D., B.Sc.Agr., M.S.
Senior Research Officer—F. W. Hely, M.Sc.Agr., M.S.
Research Officer—Miss K. Helms, M.Sc., Ph.D.
Research Officer—S. M. Bromfield, Ph.D., M.Agr.Sc.
Research Officer—F. J. Bergerson, M.Sc.
Research Officer—M. Zaitlin, Ph.D., B.S.
Technical Officer—J. Brockwell, D.D.A.
Technical Officer—Miss J. Friend, B.Sc.Agr.

Fruit Investigations, Hobart—
Principal Research Officer—D. Martin, D.Sc.
Research Officer—T. L. Lewis, B.Sc.(Hons.).
Technical Officer—J. Cerny, Ph.D.

Fruit Investigations, Queensland—
Principal Research Officer—L. A. Thomas, M.Sc.

Tobacco Investigations, Canberra—
Principal Research Officer—A. V. Hill, M.Sc.Agr.
Technical Officer—M. Mandryk, B.Sc.Agr.

Group 2—Chemistry and Physiology—
Leader—Vacant.

General Chemistry, Canberra—
Principal Research Officer—C. H. Williams, M.Sc.
Senior Research Officer—A. Steinbergs, Nut.Chem. (Riga).
Senior Research Officer—D. J. Cosgrove, B.Sc. (Hons.), Ph.D., A.R.I.C.
Research Officer—D. J. David, M.Sc.

Soil Chemistry, Melbourne—
Senior Research Officer—L. H. P. Jones, Ph.D., B.Sc.Agr.
Technical Officer—A. Sherrington, A.Sw.T.C.

Plant Nutrition, Canberra—
Senior Principal Research Officer—A. J. Anderson, B.Sc.(Agric.).
Senior Research Officer—K. D. McLachlan, B.Sc.Agr., B.Com.
Research Officer—D. Spencer, Ph.D., B.Sc. (Hons.) (abroad).
Research Officer—J. V. Possingham, B.Ag.Sc. (Hons.) (abroad).
Research Officer—J. F. Loneragan, Ph.D., B.Agr.Sc.

Plant Toxicology, Canberra—
Principal Research Officer—C. G. Greenham, M.Sc.
Research Officer—N. A. Walker, B.Sc.(Hons.).

Plant Biochemistry, Canberra—
Senior Principal Research Officer—J. E. Falk, M.A.
Research Officer—P. L. Goldacre, B.Sc., Ph.D.

Plant Biochemistry, Melbourne—
Research Officer—C. A. Appleby, B.Sc.(Hons.).

Tobacco Biochemistry, Canberra—
Senior Research Officer—R. Johanson, M.Sc.
Technical Officer—P. Macnicol, B.Sc.

Organic Chemistry, Canberra—
Research Officer—W. Bottomley, B.Sc.(Hons.), Ph.D.
Technical Officer—P. I. Mortimer, M.Sc.

Plant Physiology, Canberra—
Principal Research Officer—L. A. T. Ballard, Ph.D., M.A., M.Ag.Sc.
Research Officer—J. A. Zwar, M.Agr.Sc.
Research Officer—A. H. C. G. Rijven, Ph.D., B.Sc.
Research Officer—N. P. Kefford, M.Sc., Ph.D.

Tobacco Physiology, Canberra—
Research Officer—J. Calvert, D.Sc.

Crop Physiology, Canberra—
Principal Research Officer—R. F. Williams, M.Sc.

Group 3—Ecology and Agronomy—
Leader—R. M. Moore, M.Sc.Agr.

At Canberra—
Ecology—
Senior Principal Research Officer—R. M. Moore, M.Sc.Agr.
Research Officer—C. W. E. Moore, M.Agr.Sc.
Research Officer—L. F. Myers, M.Agr.Sc.
Research Officer—E. F. Biddiscombe, M.Agr.Sc.
Technical Officer—J. A. Robertson, Q.D.D.M.

Agronomy—
Senior Research Officer—W. D. Andrew, M.Agr.Sc.
Research Officer—W. M. Willoughby, B.Sc.Agr.
Research Officer—H. L. Davies, B.Sc.
Research Officer—R. S. J. Lipsett, B.Agr.Sc. (Hons.).
Technical Officer—J. D. Williams, D.D.A.

Dickson Experiment Station—
Technical Officer—R. J. Hutchings, D.D.A.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Native Pastures—
Principal Research Officer—R. Roe, B.Sc. (Agric.).
Research Officer—J. E. Begg, B.Sc.Agr.(Hons.).
Technical Officer—V. J. Wolfe, Q.D.A.
Technical Officer—B. E. Mottershead, B.Sc.

Sown Pastures—
Research Officer—E. J. Hilder, B.Sc.(Agric.).
Technical Officer—J. A. Thompson, B.Sc.(For.).

Plant Nutrition—
Research Officer—K. Spencer, B.Sc.Agr.(Hons.).
Technical Officer—N. J. Barrow, B.Agr.Sc.

Ecological Survey—
Senior Research Officer—R. W. Jessup, M.Sc.
Technical Officer—F. R. Gnauck, B.Sc.

Chemical Investigations—
Technical Officer—J. R. Freney, B.Sc.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—
Officer-in-charge—R. W. Prunster, B.Sc.(Agric.) (abroad).

Ecology—
Research Officer—O. B. Williams, M.Agr.Sc.

Hydrology—
Research Officer—J. R. Philip, B.C.E. (abroad).

Chemistry—
Technical Officer—R. J. Hunter, B.Sc.

Production and Utilization—
Research Officer—R. N. J. Bickerdike, B.A.

Agronomy—
Research Officer—M. J. Barneveld, M.Sc.
Technical Officer—Miss V. E. Rogers, B.A.

At Mitchell Laboratory, Trangie, New South Wales—
Research Officer—A. A. Holland, M.Sc.Agr.

At Irrigation Research Station, Griffith, New South Wales—
Ecology—
Research Officer—E. Levi, M.Sc.

At University of Queensland, Brisbane—
Ecology—
Senior Research Officer—L. J. Webb, M.Sc.

At Waite Institute, Adelaide, South Australia—
Oil Crop Investigations—
Senior Research Officer—B. Horowitz, D.Agr.Sc.
Research Officer—W. J. Lovett, B.Agr.Sc.
Technical Officer—C. R. Kleinig, B.Ag.Sc.(Hons.).

At Institute of Agriculture, Perth, Western Australia—
Plant Nutrition—
Principal Research Officer—R. C. Rossiter, D.Sc. Agr.
Research Officer—P. G. Ozanne, B.Sc.(Agric.).
Technical Officer—R. J. Pack, Q.D.A.

Agronomy—
Research Officer—A. W. Humphries, B.Sc.(Agric.) (Hons.).
Technical Officer—D. J. Kirton, B.Sc.(Agric.).
Chemistry—
Technical Officer—T. Shaw, B.Sc.
Plant Introduction—
Senior Research Officer—E. T. Bailey, B.Sc.
Technical Officer—N. B. Gayfer, D.D.A.
At "Glen Lossie" Field Station, Kojonup, Western Australia—
Research Officer—E. R. Watson, B.Sc.(Agric.), M.Sc.(Agric.).
Technical Officer—P. Lapins, M.Agr.Sc.
Technical Officer—J. Beresford, D.D.A.
Group 4—Agrostology and Agronomy (Queensland)—
Leader—J. Griffiths Davies, B.Sc., Ph.D.
Agrostology—
Principal Research Officer—T. B. Paltridge, B.Sc. (Hons.).
Agronomy—
Principal Research Officer—W. W. Bryan, M.Agr.Sc.
Research Officer—S. G. Gray, B.Sc.Agr.
Technical Officer—B. B. Brett, B.Agr.Sc., Q.D.A.
Regional Trials—
Technical Officer—L. A. Edye, B.Agr.Sc.(Hons.).
Cattle Pastures—
Senior Research Officer—N. H. Shaw, B.Sc.Agr. (Hons.).
Technical Officer—O. T. Denmead, B.Agr.Sc.
Technical Officer—T. W. Elich, Dip.Col.Agr.
Plant Nutrition—
Senior Research Officer—C. S. Andrew, B.Agr.Sc.
Research Officer—R. G. Coleman, Ph.D., B.Sc. Agr., D.I.C.
Technical Officer—W. H. J. Pieters, Dip.Col.Agr.
Plant Chemistry—
Research Officer—M. P. Hegarty, Ph.D., M.Sc.
Technical Officer—Miss P. M. Thorne, B.Sc.
Ecology—
Senior Research Officer—J. E. Coaldrake, M.Sc.
Technical Officer—W. F. Ridley, B.Sc.
Genetics—
Principal Research Officer—E. M. Hutton, D.Sc., B.Ag.Sc.
Legume Bacteriology—
Principal Research Officer—D. O. Norris, D.Sc. (Agric.).
Plant Introduction—
Principal Research Officer—J. F. Miles, M.Agr.Sc.
Research Officer—E. H. Kipps, B.Sc.
At Cooper Laboratory, Lawes, Queensland—
Research Officer—W. J. Bisset, B.Agr.Sc.
Technical Officer—R. Milford, B.Sc., Q.D.A.
Technical Officer—H. Kiers, Dip.Col.Agric.

32. Division of Radio Physics.

(Head-quarters: University Grounds, Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.
Assistant Chief—J. L. Pawsey, F.R.S., M.Sc., Ph.D.
Technical Secretary—A. J. Higgs, B.Sc.
Assistant Technical Secretary—L. L. McCready, B.Sc., B.E.
Cloud and Rain Physics—
Principal Research Officer—J. Warner, B.Sc., B.E.
Principal Research Officer—P. Squires, M.A.
Principal Research Officer—E. J. Smith, M.B.E., B.Sc.(Eng.).
Research Officer—N. R. Labrum, B.Sc.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—E. K. Bigg, M.Sc., Ph.D.
Research Officer—S. Twomey, M.Sc., Ph.D.
Research Officer—J. M. Telford, B.Sc.
Radio Astronomy—
Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Principal Research Officer—B. Y. Mills, B.Sc., M.E.
Principal Research Officer—W. N. Christiansen, D.Sc.
Senior Research Officer—F. J. Kerr, M.Sc., M.A.
Research Officer—S. F. Smerd, B.Sc.
Research Officer—C. A. Shain, B.Sc.
Research Officer—J. A. Roberts, M.Sc., Ph.D.
Research Officer—R. X. McGee, B.Sc.(Hons.).
Research Officer—J. A. Warburton, B.Sc.(Hons.).
Research Officer—R. F. Mullaly, M.Sc.
Research Officer—A. W. L. Carter, B.Sc.(Hons.).
Research Officer—A. G. Little, B.Sc., A.S.T.C.
Senior Technical Officer—K. V. Sheridan, B.Sc.
Senior Technical Officer—J. V. Hindman.
Senior Technical Officer—K. R. McAlister, A.S.T.C.
Senior Technical Officer—J. D. Murray, B.Sc. (Eng.).
Technical Officer—O. B. Slee, A.S.T.C.
Technical Officer—M. M. Komesaroff, B.Sc.
Technical Officer—R. L. Dowden, B.Sc.
Radio Navigation—
Principal Research Officer—H. C. Minnett, B.Sc., B.E.
Research Officer—G. A. Day.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer—F. F. Gardner, B.Sc., B.E., Ph.D.
Senior Technical Officer—P. T. Hedges, A.S.T.C.
Technical Officer—R. S. Joseph, A.S.T.C.
Technical Officer—I. K. Harvey, A.S.T.C.
Physics of Semi-conductors—
Senior Research Officer—B. F. C. Cooper, B.Sc. (Hons.), B.E.
Research Officer—L. W. Davies, B.Sc.(Hons.), D.Phil.
Research Officer—R. D. Ryan, B.Sc., B.E.
Senior Technical Officer—F. C. Tonking, A.S.T.C.
Technical Officer—B. M. Bartlett, B.Sc.
Mathematical Computation—
Principal Research Officer—T. Pearcey, B.Sc. (Hons.).
Principal Research Officer—M. Beard, B.Sc., B.E.
Research Officer—G. W. Hill, M.Sc.
Technical Officer—R. T. H. Bowles, A.M.T.C.
Technical Officer—G. A. Chandler, A.S.T.C.
Test Room—
Senior Technical Officer—G. A. Wells, A.S.T.C.
Technical Officer—T. E. Cousins, A.S.T.C.
Engineering Services—
Chief Draughtsman—F. M. Carter.
Draughtsman, Grade II.—H. F. Peddie, A.S.T.C.
Draughtsman, Grade II.—J. R. Morris.
Officers Abroad—
Principal Research Officer—J. G. Bolton, B.A.
Senior Research Officer—R. N. Bracewell, B.Sc., B.E., Ph.D.
Senior Research Officer—J. P. Wild, M.A.
Research Officer—J. S. Turner, M.Sc.
Research Officer—E. R. Hill, M.Sc.
Research Officer—N. H. Fletcher, B.Sc.(Hons.), M.A.
Senior Technical Officer—G. J. Stanley, A.S.T.C.

33. Radio Research Board.

(Head-quarters: University of Sydney.)

Chief Scientific Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.S., F.R.S.
Senior 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—R. A. Duncan, B.Sc.
Technical Officer—L. H. Heisler, B.Sc.
Technical Officer—H. P. Hirschl, B.E., A.S.T.C.
Technical Officer—R. B. White, B.E.

34. 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.
Senior Clerical Officer—F. W. Blanksby.
Soil Survey and Pedology Section—
Senior Principal Research Officer—C. G. Stephens, D.Sc.
Senior Research Officer—K. H. Northcote, B.Agr.Sc.
Senior Research Officer—G. Blackburn, B.Agr.Sc.
Research Officer—E. A. Jackson, B.Ag.Sc.
Research Officer—C. B. Wells, B.Ag.Sc.
Research Officer—T. Poutsma, B.Sc.(Agric.).
Research Officer—Ir. C. J. de Mooy (l.i.).
Sectional Draughtsman—P. D. Hooper.
Soil Chemistry Section—
Principal Chemist—C. S. Piper, D.Sc.
Principal Research Officer—A. C. Oertel, M.Sc.
Senior Research Officer—R. E. Shapter, A.A.C.I.
Senior Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M.
Research Officer—H. C. T. Stace, M.Sc.
Research Officer—B. M. Tucker, B.Sc.(Hons.).
Research Officer—R. S. Beckwith, B.Sc.(Hons.).
Research Officer—M. Raupach, M.Sc. (abroad).
Technical Officer—A. R. P. Clarke, A.S.A.S.M.
Technical Officer—R. M. McKenzie, A.S.A.S.M.
Technical Officer—R. D. Bond, A.S.A.S.M., A.A.C.I.
Technical Officer—K. G. Tiller, B.Sc.
Technical Officer—Ir. M. P. C. de Vries (l.i.).
Soil Physics Section—
Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Research Officer—J. P. Quirk, B.Sc.Agr.(Hons.)., Ph.D.
Research Officer—J. W. Holmes, M.Sc.
Research Officer—C. G. Gurr, B.Sc.
Research Officer—D. S. McIntyre, M.Sc.
Soil Microbiology Section—
Principal Research Officer—R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.
Research Officer—J. R. Harris, M.Sc.
Research Officer—J. N. Ladd, M.Sc.
Technical Officer—Miss J. I. Sperber, B.Sc.
Soil Mechanics Section—
Senior Research Officer—G. D. Aitchison, M.E. (at University of Melbourne).
Research Officer—I. B. Donald, B.C.E.
Soil Mineralogy Section—
Senior Research Officer—K. Norrish, M.Sc., Ph.D.
Research Officer—E. W. Radoslovich, M.Sc.
Research Officer—Mrs. L. E. R. Rogers, M.Sc.

At Brisbane—
Soil Survey and Pedology Section—
Principal Research Officer—G. D. Hubble, B.Ag.Sc.
Research Officer—G. G. Beckmann, B.Sc.
Research Officer—W. H. Litchfield, B.Sc.Agr.
Technical Officer—C. H. Thompson, Q.D.A.
Soil Physics—
Research Officer—G. B. Stirk, B.Sc.
Technical Officer—R. E. Prebble, B.Sc.
Soil Chemistry—
Senior Research Officer—A. E. Martin, B.Sc., F.R.I.C.
Technical Officer—R. Reeve, Dip.Ind.Chem.
Technical Officer—H. J. Beatty, Dip.Ind.Chem.
Technical Officer—Miss J. Richardson, B.Sc.

At Canberra—
Soil Survey and Pedology Section—
Principal Research Officer—B. E. Butler, B.Sc. (Agric.).
Senior Research Officer—R. Brewer, B.Sc.(Hons.).
Research Officer—D. C. van Dijk, Ing.Agr., D.Sc.
Research Officer—J. R. Sleeman, B.Agr.Sc. (seconded to Land Research and Regional Survey Section).
Research Officer—H. M. Churchward, B.Sc.Agr. (Hons.) (at Deniliquin).
Technical Officer—Miss M. P. Green, B.Sc.
Soil Chemistry—
Research Fellow—A. Wild, B.Sc., Ph.D.
Senior Technical Officer—A. D. Haldane, B.Sc.
Technical Officer—Mrs. M. R. Reid, M.Sc.
Soil Physics—
Technical Officer—A. V. Blackmore, B.Sc.

At Hobart—
Soil Survey and Pedology Section—
Senior Research Officer—K. D. Nicolls, B.Agr.Sc., B.Sc.
Research Officer—G. M. Dimmock, B.Sc.
Research Officer—J. Loveday, M.Ag.Sc.
Soil Chemistry—
Technical Officer—A. M. Graley, B.Sc.

At Perth—
Soil Survey and Pedology Section—
Research Officer—M. J. Mulcahy, B.Sc.
Research Officer—L. W. Pym, B.Sc.(Agric.).
Research Officer—W. M. McArthur, B.Sc.(Hons.).
Technical Officer—E. Bettenay, B.Sc.(Agric.).
Soil Chemistry—
Research Officer—A. G. Turton, B.Sc.
Technical Officer—F. J. Hingston, B.Sc.

Officers on Studentships—
A. D. Rovira, M.Agr.Sc.

35. Tracer Elements Investigations.

(Head-quarters: Chemistry School, University of Melbourne.)

Senior Research Officer—A. M. Downes, M.Sc.
Research Officer—K. R. Lynn, B.Sc.(Hons.).

36. Division of Tribophysics.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, D.Ing., M.Sc.
Principal Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc., A.G.Inst.Tech.
Senior Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc.
Senior Research Officer—M. E. Hargreaves, Ph.D., B.Met.E.
Senior Research Officer—J. K. Mackenzie, Ph.D., B.A. (Hons.), B.Sc.
Senior Research Officer—A. J. W. Moore, Ph.D., B.Sc.
Senior Research Officer—R. G. Vines, M.Sc.
Research Officer—B. D. Cuming, M.Sc., Ph.D.
Research Officer—A. J. Davis, B.Eng. (abroad).
Research Officer—E. Gillam, B.Sc., M.S.(Calif.).
Research Officer—D. F. Klemperer, Ph.D.
Research Officer—D. Michell, B.E.E.
Research Officer—J. F. Nicholas, B.A.(Hons.), B.Sc.
Research Officer—G. J. Ogilvie, Ph.D., B.Met.E., M.Eng.Sc.
Research Officer—M. J. Ridge, M.Sc.

Research Officer—J. V. Sanders, Ph.D., B.Sc.(Hons.).
Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Research Officer—J. A. Spink, M.Sc. (abroad).
Research Officer—G. W. West, B.E.E., B.Sc.
Technical Officer—J. J. Batten, B.Sc.
Technical Officer—G. Brinson, B.Sc.
Technical Officer—E. D. Hondros, B.Sc.
Technical Officer—G. R. Perger, F.M.T.C.
Technical Officer—R. G. Sherwood, A.M.T.C.
Technical Officer—W. J. McG. Tegart, M.Sc., A.M.T.C.
Technical Officer—A. J. White, A.R.M.T.C.

37. Wildlife Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-charge—F. N. Ratcliffe, B.A.
Principal Research Officer—R. Carrick, B.Sc., Ph.D.
Sectional Secretary—F. N. Robinson, B.A.
Research Officer—A. L. Dyce, B.Sc.Agr.(Hons.).
Research Officer—B. J. G. Marlow, B.Sc.
Research Officer—R. Mykytowycz, D.V.M.
Technical Officer—I. C. R. Rowley, B.Agr.Sc.
Technical Officer (Librarian)—Miss N. Turnbull, B.Sc.

At Perth, Western Australia—
Principal Research Officer—D. L. Serventy, B.Sc., Ph.D.
Research Officer—J. H. Calaby, A.B.S.M.
Research Officer—G. M. Dunnet, B.Sc., Ph.D.

At Woodstock, Western Australia—
Research Officer—E. H. M. Ealey, M.Sc.

At Albury, New South Wales—
Senior Research Officer—K. Myers, B.Sc.(Hons.).
Research Officer—G. W. Douglas, B.Agr.Sc. (Hons.).
Research Officer—W. E. Poole, B.Sc.(Hons.).

At Griffith, New South Wales—
Senior Research Officer—H. J. Frith, B.Sc.Agr.

At Armidale, New South Wales—
Senior Research Officer—B. V. Fennessy, B.Agr.Sc.
Technical Officer—E. J. Waterhouse, B.Ag.Sc.

38. Wool Textile Research Laboratories.

Senior Officer-in-charge—F. G. Lennox, D.Sc.

At Wool Textile Research Laboratory, Melbourne—
Biochemistry Unit, 343 Royal-parade, Parkville, Victoria—
Officer-in-charge—F. G. Lennox, D.Sc.
Laboratory Secretary—C. Garrow, B.Com., D.P.A., A.A.S.A.
Principal Research Officer—H. Lindley, B.A., Ph.D. (abroad).
Principal Research Officer—W. G. Crewther, M.Sc.
Senior Research Officer—T. A. Pressley, B.Sc.
Senior Research Officer—J. M. Gillespie, M.Sc.
Senior Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Senior Research Officer—S. J. Leach, B.Sc.Tech., Ph.D.
Senior Research Officer—E. F. Woods, M.Sc., A.M.T.C.
Senior Research Officer—J. M. Swan, B.Sc., Ph.D., D.I.C.
Senior Research Officer—R. D. B. Fraser, Ph.D.
Research Officer—W. E. Savige, Ph.D.
Research Officer—E. O. P. Thompson, M.Sc., Dip.Ed., Ph.D.
Research Officer—J. P. E. Human, Ph.D.
Research Officer—D. H. Simmonds, M.Sc., Ph.D.
Research Officer—I. J. O'Donnell, M.Sc.
Research Officer—B. S. Harrap, Ph.D.
Research Officer—G. E. Rogers, M.Sc. (abroad).
Research Officer—P. H. Springell, M.A., Ph.D.
Research Officer—J. A. Maclaren, Ph.D.
Research Officer—G. Youatt, Ph.D.
Research Officer—T. P. MacRae, M.Sc.
Technical Officer—A. B. McQuade, B.Sc.
Technical Officer—I. G. Stell, A.Sw.T.C.
Technical Officer—K. I. Wood, A.M.T.C.
Technical Officer—S. V. Brasch, B.Sc., A.G.Inst. Tech.

At Wool Textile Research Laboratory, Sydney—
Physics and Engineering Unit, The Hermitage, 338 Blaxland-road, Ryde, New South Wales—
Officer-in-charge—V. D. Burgmann, B.Sc., B.E. (Hons.).
Technical Secretary—H. W. M. Lunney, B.Sc., B.E.
Principal Research Officer—J. G. Downes, B.Sc.
Principal Research Officer—N. F. Roberts, M.Sc.
Senior Research Officer—H. W. Holdaway, B.Sc., B.E.
Senior Research Officer—M. Feughelman, B.Sc. (Hons.), A.S.T.C.
Senior Research Officer—Mrs. K. R. Makinson, B.A.(Hons.), F.Inst.P.
Research Officer—E. G. Bendit, M.Sc.
Research Officer—J. F. P. James, M.Sc.
Research Officer—M. Chaikin, B.Sc., Ph.D., Dip. Eng.
Research Officer—I. M. Stuart, M.Sc.
Research Officer—P. Nordon, B.Sc.(Hons.), A.S.T.C.
Research Officer—M. W. Andrews, B.Sc.(Hons.).
Research Officer—K. Baird, M.Sc.
Research Officer—Miss V. Laws, M.Sc.
Senior Technical Officer—B. G. Leary, A.S.T.C.
Technical Officer—Miss J. C. Griffith, B.Sc., A.S.T.C.
Technical Officer—B. J. Rigby, A.S.T.C.
Technical Officer—A. G. Stutter, B.Sc.(Hons.).
Technical Officer—A. R. Haly, B.Sc.

At Wool Textile Research Laboratory, Geelong, Victoria—
Officer-in-charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary—T. Topham, A.M.I.I.A., A.T.I.
Senior Research Officer—D. L. C. Jackson, B.Sc.
Senior Research Officer—G. W. Walls. B.Sc.
Research Officer—C. A. Anderson, B.Sc.
Research Officer—J. H. Bradbury, M.Sc., Ph.D.
Research Officer—J. Delmenico, B.Sc.(Hons.).
Research Officer—A. J. Farnworth, M.Sc., Ph.D., A.G.Inst.Tech.
Research Officer—J. R. McPhee, B.Sc., D.Phil.
Research Officer—C. H. Nicholls, B.Sc.(Hons.), Ph.D.
Research Officer—D. S. Taylor, B.A., B.Sc., Ph.D.
Technical Officer—M. A. Higgins, A.G.Inst.Tech.
Technical Officer—B. O. Lavery.
Technical Officer—P. R. Strutt, B.Sc.
Technical Officer—G. C. West, A.G.Inst.Tech.

XXXIV. PUBLISHED PAPERS.

The following papers have been published during the year:—

1. Animal Genetics Section.

Dowling, D. F. (1954).—The induction of ovulation in cattle. *Aust. Vet. J.* 30:240-3.

Dowling, D. F., *and* Carter, H. B. (1954).—The hair follicle and apocrine gland population of cattle skin. *Aust. J. Agric. Res.* 5:745-54.

Fraser, A. S. (1954).—Development of the skin follicle population in Merino sheep. *Aust. J. Agric. Res.* 5:737-43.

Nay, T., *and* Fraser, A. S. (1954).—Growth of the mouse coat. III. Patterns of hair growth. *Aust. J. Biol. Sci.* 7:361-7.

Rendel, J. M. (1954).—Use of regressions to increase heritability. *Aust. J. Biol. Sci.* 7:368-78.

Sobey, W. R., *and* Adams, K. M. (1955).—A report on the Hellige haemoscope. *Med. J. Aust.* 1:527-9.

2. Division of Animal Health and Production.

Alexander, G., McCance, I., *and* Watson, R. H. (1955).—Some observations on losses among Merino lambs. Age at death, birth weight and duration of gestation of the lambs from one flock. *Aust. Vet. J.* 31:85-90.

Austin, C. R., *and* Braden, A. W. H. (1954).—Anomalies in rat, mouse, and rabbit eggs. *Aust. J. Biol. Sci.* 7:537-42.

Austin, C. R., *and* Braden, A. W. H. (1955).—Observations on nuclear size and form in living rat and mouse eggs. *Exp. Cell Res.* 8:163-72.

Braden, A. W. H. (1954).—Infertility in rats and mice following oestrogen treatment early in life. *Endocrinology.* 55:112-3.

Braden, A. W. H. (1955).—The reactions of isolated mucopolysaccharides to several histochemical tests. *Stain Tech.* 30:19-26.

Braden, A. W. H., *and* Austin, C. R. (1954).—The fertile life of mouse and rat eggs. *Science.* 120:610-11.

Braden, A. W. H., *and* Austin, C. R. (1954).—The number of sperms about the eggs in mammals and its significance for normal fertilization. *Aust. J. Biol. Sci.* 7:543-51.

Braden, A. W. H., *and* Austin, C. R. (1954).—Fertilization of the mouse egg and the effect of delayed coitus and hot-shock treatment. *Aust. J. Biol. Sci.* 7:552-65.

Braden, A. W. H., *and* Austin, C. R. (1954).—Reactions of unfertilized mouse eggs to some experimental stimuli. *Exp. Cell Res.* 7:277-80.

Braden, A. W. H., Austin, C. R., *and* David, H. A.* (1954).—Reaction of the zona pellucida to sperm penetration. *Aust. J. Biol. Sci.* 7:391-409.

Bremner, K. C. (1954).—Cytological polymorphism in the nematode *Haemonchus contortus* (Rudolphi 1803) Cobb 1898. *Nature.* 174:704-5.

Bull, L. B. (1955).—The histological evidence of liver damage from pyrrolizidine alkaloids: megalocytosis of the liver cells and inclusion globules. *Aust. Vet. J.* 31:33-40.

Carter, H. B., *and* Dowling, D. F.† (1954).—The hair follicle and apocrine gland population of cattle skin. *Aust. J. Agric. Res.* 5:745-54.

Cymerman-Craig, J.,** Rogers, W. P., *and* Warwick, G. P.** (1955).—Chemical constitution and anthelmintic activity. II. Preparation of some analogues of phenothiazine. *Aust. J. Chem.* 8:252-7.

Daly, R. A., *and* Carter, H. B. (1955).—The fleece growth of young Lincoln, Corriedale, Polwarth, and fine Merino maiden ewes under housed conditions and unrestricted and progressively restricted feeding on a standard diet. *Aust. J. Agric. Res.* 6:476-513.

Dick, A. T. (1954).—Preliminary observations on the effect of high intakes of molybdenum and of inorganic sulphate on blood copper and on fleece character in Crossbred sheep. *Aust. Vet. J.* 30:196-202.

* Division of Mathematical Statistics, McMaster Laboratory.
† Animal Genetics Section, C.S.I.R.O.
** Department of Chemistry, University of Sydney.

Dick, A. T. (1954).—Studies on the assimilation and storage of copper in Crossbred sheep. *Aust. J. Agric. Res.* 5:511-44.

Dunlop, A. A., *and* Turner, Helen Newton* (1955).—The effect of length of wool in the manual tautening of skin areas on the live sheep. *Aust. J. Agric. Res.* 6:109-14.

Durie, P. H. (1955).—A technique for the collection of large numbers of paramphistome (Trematoda) metacercariae. *Aust. J. Agric. Res.* 6:200-2.

Ferguson, K. A. (1954).—Prolonged stimulation of wool growth following injections of ox growth hormone. *Nature.* 174:411.

Franklin, M. C., McClymont, G. L.,† Briggs, P. K., *and* Campbell, B. L. (1955).—Maintenance rations for Merino sheep. II. The performance of weaners fed daily and weekly on rations of wheat and wheaten chaff at maintenance levels and the effect thereon of vitamin A supplements. *Aust. J. Agric. Res.* 6:324-42.

Gordon, H. McL. (1955).—Fascioliasis, with particular reference to acute fluke disease. *Aust. Vet. J.* 31:46-7.

Hayman, R. H. (1955).—Studies in fleece-rot of sheep: some ecological aspects. *Aust. J. Agric. Res.* 6:466-75.

Hayman, R. H., Turner, Helen Newton,* *and* Turton, Enid* (1955).—Observations on survival and growth to weaning of lambs from ewes with defective udders. *Aust. J. Agric. Res.* 6:446-55.

Heppel, L. A.,** *and* Whitfeld, P. R. (1955).—Nucleotide exchange reactions catalysed by ribonuclease and spleen phosphodiesterase. 1. Synthesis and interconversion of simple esters of ribomononucleotides. *Biochem. J.* 60:1-7.

Heppel, L. A.,** Whitfeld, P. R., *and* Markham, R.** (1955).—Nucleotide exchange reactions catalysed by ribonuclease and spleen phosphodiesterase. 2. Synthesis of polynucleotides. *Biochem. J.* 60:8-15.

Heppel, L. A.,** Whitfeld, P. R., *and* Markham, R.** (1955).—A note on the structure of triphosphopyridine nucleotide. *Biochem. J.* 60:19-21.

Legge, J. W.,†† *and* Turner, A. W. (1954).—Bacterial oxidation of arsenite. III. Cell-free arsenite dehydrogenase. *Aust. J. Biol. Sci.* 7:496-503.

Munch-Petersen, E. (1954).—*Actinomyces (Nocardia)* sp. from a bovine udder infection. *Aust. Vet. J.* 30:297-300.

Munch-Petersen, E. (1954).—A corynebacterial agent which protects ruminant erythrocytes against staphylococcal β toxin. *Aust. J. Exp. Biol. Med. Sci.* 32:361-8.

Murray, M. D. (1955).—Infestation of sheep with the face louse (*Linognathus ovillus*). *Aust. Vet. J.* 31:22-6.

Radford, H. M., *and* Watson, R. H. (1955).—Changes in the vaginal contents of the Merino ewe throughout the year. *Aust. J. Agric. Res.* 6:431-45.

Riches, J. H., *and* Turner, Helen Newton* (1955).—A comparison of methods of classing flock ewes. *Aust. J. Agric. Res.* 6:99-108.

Rick, R. F. (1955).—Studies on allergic dermatitis (Queensland itch) of the horse: the origin and significance of histamine in the blood and its distribution in the tissues. *Aust. J. Agric. Res.* 6:161-70.

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XXXV.—FINANCE.

1. Expenditure.

The statement of expenditure from 1st July, 1954, to 30th June, 1955, is as follows:—

	£	£	£
(a) Salaries and contingencies			242,408*
(b) Investigations—			
(i) Animal Health and Production Problems		533,061	
Less contributions from—			
Wool Research Trust Account	218,526		
Commonwealth Bank	218		
Australian Dairy Produce Board	2,218		
Australian Meat Board	5,085		
George Aitken Pastoral Research Trust	500		
Ian McMaster Bequest	5,410		
Alex. Fraser Memorial Fund	300		
Wm. McIlrath Fellowship	2,517		
Department of Territories	425		
J. L. Wilson	100		
Burdekin Bequest (Drought feeding)	1,700		
Wool Industry Fund *Dr.*	250A		
Special Revenue Funds—			
Burdekin Bequest	1,492		
"Gilruth" Plains Field Station	23,943		
Belmont Field Station	954		
		263,138	
			269,923
(ii) Biochemistry and General Nutrition Problems		102,108	
Less contributions from—			
Wool Research Trust Account	37,994		
		37,994	
			64,114
(iii) Plant Problems—Division of Plant Industry		554,858	
Less contributions from—			
Wool Research Trust Account	96,658		
		96,658	
			458,200
(iv) Entomology Problems			108,400
(v) Soils and Irrigation Problems of Irrigation Settlements—			
(*a*) Citricultural—Research Station, Griffith		39,802	
Less contributions from—			
N.S.W. Water Conservation and Irrigation Commission	2,000		
Special Revenue Fund—Griffith Research Station	2,401		
		4,401	
			35,401
(*b*) Viticultural—Research Station, Merbein		59,415	
Less contributions from—			
Dried Fruits Control Board	1,600		
Mildura Co-op. Fruit Company	250		
Irymple Packing Company	250		
Red Cliffs Co-op. Fruit Company	250		
Aurora Packing Company	250		
Co-op. Dried Fruit Sales Ltd.	250		
Nyah-Woorinen Enquiry Committee	75		
		2,925	
			56,490
			91,891
(vi) Soil Problems			161,433
(vii) Food Preservation and Transport Problems		179,423	
Less contributions from—			
N.S.W. Department of Agriculture	2,026		
Metropolitan Meat Industry Commission	500		
Queensland Meat Industry Board	1,275		
Australian Meat Board	500		
Australian Egg Board	750		
Commonwealth Can Makers' Association	352		
Department of Commerce and Agriculture	7,486		
Apple and Pear Board	62		
Various Contributors	636		
		13,587	
			165,836
(viii) Forest Products Problems		240,654	
Less contributions from—			
Australian Paper Manufacturers Ltd.	1,000		
Associated Pulp and Paper Mills Ltd.	1,000		
Australian Newsprint Mills	1,000		
New Zealand Forest Products Ltd.	500		
Department of Territories	2,897		
General Donations	101		
Wooden Case Manufacturers' Association	165		
		6,663	
			233,991
(ix) Mining and Metallurgy		29,387	
Less contributions from—			
Australasian Institute of Mining and Metallurgy	1,000		
		1,000	
			28,387
(x) Radio Research		37,346	
Less contributions from—			
Postmaster-General's Department	9,338		
		9,338	
			28,008

* 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 general office expenditure.

A.—Relates to adjustment of expenditure between Wool Industry Fund and Wool Research Trust Account.

	£	£	£
(xi) Research Services		187,694	
Less contribution from—			
Wool Research Trust Account	4,756		
		4,756	
			182,938
(xii) Industrial Chemistry		439,850	
Less contributions from—			
National Gas Association	133		
Cement and Concrete Association	1,500		
Mt. Morgan Ltd. and Mt. Lyell Mining and Railway Co. Ltd.	4,581		
Australian Atomic Energy Commission	15,866		
Various Contributors	150		
		22,230	
			417,620
(xiii) Fisheries Investigations		147,183	
Less contributions from—			
N.S.W. Government	250		
Department of the Navy	1,057		
		1,307	
			145,876
(xiv) Mathematical Statistics			57,587
(xv) National Standards Laboratory			429,661
(xvi) Tribophysics			71,591
(xvii) Building Research			119,068
(xviii) Plant Fibre Research			33,237
(xix) Radiophysics Research			275,441
(xx) Metallurgical Research			9,854
(xxi) Nuclear Energy Research			12,618
(xxii) Meteorological Physics		53,671	
Less contribution from—			
Committee for Dried Fruit Marketing	328		
		328	
			53,343
(xxiii) Dairy Research		42,615	
Less contribution from—			
Australian Dairy Produce Board	188		
		188	
			42,427
(xxiv) Wool Textile Research		266,812	
Less contributions from—			
Wool Research Trust Account	257,394		
Department of Supply	1,000		
Associated Woollen and Worsted Textile Manufacturers of Australia.	1,764		
		260,158	
			6,654
(xxv) Fuel Research			116,626
(xxvi) Wildlife Survey		83,117	
Less contribution from—			
Wool Research Trust Account	41,880		
George Aitken Pastoral Research Trust	1,206		
		43,086	
			40,031
(xxvii) Land Research and Regional Survey		105,692	
Less contributions from—			
Department of National Development	18,353		
Department of Territories	11,949		
		30,302	
			75,390
(xxviii) Genetics		27,834	
Less contribution from—			
Wool Research Trust Account	13,917		
		13,917	
			13,917
(xxix) Miscellaneous—			
(*a*) Biophysical Research		1,846	
(*b*) Oenological Research		6,181	
(*c*) Extra-mural Investigations		8,300	
(*d*) Farm Mechanization Research		5,606	
(*e*) Various		5,970	
		27,903	
Less contributions from—			
Australian Wine Board	3,090		
Science and Industry Endowment Fund	719		
Commonwealth Bank	5,000		
Australian Dairy Produce Board	500		
		9,309	
			18,594
(xxx) Unforeseen and Urgent			
Total of Item (*b*)—Investigations			3,792,656
(*c*) Grants—			
(i) Research Associations—			
Leather Research Association	7,500		
Bread Research Institute	7,500		
		15,000	
(ii) Overseas Research Studentships		33,700	
		48,700	
Less contributions from—			
Wool Research Trust Account	2,918		
Science and Industry Endowment Fund	1,985		
		4,903	
			43,797
Total Salaries and Contingencies, Investigations, and Grants			4,078,861
Less receipts from sales of equipment, publications, &c., and revenue earned by Divisions and Sections, details of which are shown in Section 5			89,543
			3,989,318

2. Contributions and Donations.

The following statement shows the receipts and disbursements during the year 1954-55 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund" (formerly "The Specific Purposes Trust Account") —with the exception of the Wool Industry Fund, details of which appear in Section 4:—

	Receipts 1954-55 and balances brought forward from 1953-54.	Expenditure 1954-55.
	£	£
Commonwealth Bank (Animal Health and Production) Genetics, and Farm Mechanization Investigations)	5,526	5,218
Australian Wool Board (Biochemistry and General Nutrition Investigations—Sheep Research)	882	..
Australian Dairy Produce Board (Mastitis Investigations)	2,000	2,000
George Aitken Pastoral Research Trust (Animal Health and Production Investigations)	500	500
W. McIlrath Research Fellowship Fund (Expenses of Fellowship—Animal Husbandry)	2,517	2,517
Australian Meat Board (Cattle Breeding Investigations)	5,796	4,443A
Australian Meat Board (Caseous Lymphadenitis Investigations—Animal Health and Production)	399	..
Australian Meat Board (Bovine Pleuropneumonia Investigations)	90	..
Australian Meat Board (Parasitological Studies of Cattle)	867	436
Australian Dairy Produce Board (Parasitological Studies of Cattle)	434	218
Alexander Fraser Memorial Fund (Animal Health and Production Investigations)	300	300
N.S.W. State Cancer Council (Animal Health and Production—Cancer Research Project)	750	..
Department of Territories (Importation of Cattle from Pakistan)	425	425
J. L. Wilson—Studies of Tick Resistance of Cattle (Animal Health and Production Investigations)	100	100
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	5,728	5,410
United Graziers' Association of Queensland—Studies of Tick Resistance of Cattle (Animal Health and Production Investigations)	1,000	1,000B
West Australian Golf Association (Plant Industry Investigations)	51	..
United Graziers' Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Entomology)	172	..
General Donations (Division of Entomology)	12	..
Burdekin Bequest (Drought Feeding Investigations)	1,700	1,700
N.S.W. Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station)	2,000	2,000
Mildura Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Irymple Packing Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Red Cliffs Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	250	250
Co-op. Dried Fruit Sales Ltd. (Dried Vine Fruits Investigations, Merbein)	250	250
Dried Fruits Control Board (Dried Fruits Investigations)	1,600	1,600
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	440	75
Australian Dried Fruits Association (Packing House Methods Investigations)	2,855	2,855C
Australian Meat Board (Meat Investigations)	500	500
Metropolitan Meat Industry Board of New South Wales (Meat Investigations)	500	500
Queensland Meat Industry Board (Meat Investigations)	1,275	1,275
Department of Commerce and Agriculture (Mutton Dehydration Investigations)	7,601	7,486
N.S.W. Department of Agriculture (Food Investigations)	1,000	1,000
Vita Food Supply Co. (Food Investigations)	3	3
W. Angliss Ltd. (Division of Food Preservation and Transport)	51	..
Cottees Passiona Ltd. (Food Investigations)	6	6
L. Berger and Sons (Division of Food Preservation and Transport)	100	..
Various Contributors (Division of Food Preservation and Transport—Fruit Products and Canning Investigations)	627	627
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	750	750
Commonwealth Can Makers' Association (Division of Food Preservation and Transport—Tinplate Investigations)	500	352
N.S.W. Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport)	1,021	1,026D
Australian Paper Manufacturers Ltd. (Paper Pulp Investigations)	1,409	1,000
Australian Newsprint Mills (Paper Pulp Investigations)	1,000	1,000
Associated Pulp and Paper Mills Ltd (Paper Pulp Investigations)	1,000	1,000
New Zealand Forest Product Ltd. (Paper Pulp Investigations)	500	500
Sundry Contributors (Forest Products Investigations)	4,636	101
Wooden Case Manufacturers (Forest Products Investigations)	165	165
Department of Territories (Development of Pulp and Paper Industry in New Guinea)	3,058	2,897
Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations)	1,000	1,000
Postmaster-General's Department (Radio Research)	9,400	9,338
Drug Houses of Australia (Division of Fisheries—Agar Production)	25	..
Miscellaneous Contributors (Division of Industrial Chemistry)	1,495	150
Commonwealth Fertilizers and Chemicals (Industrial Chemistry)	300	..
Department of Supply (Textile Degradation Investigations)	1,000	1,000
National Gas Association (Gas Investigations — Industrial Chemistry)	133	133
Mt. Morgan Ltd. and Mt. Lyell Mining and Railway Co. Ltd. (Industrial Chemistry—Co-operative Investigtions)	4,745	4,581
N.S.W. Government (Fisheries Investigations)	250	250
State Electricity Commission of Victoria (Mineragraphic Investigations—Geological Consultations)	500	..
Australian Atomic Energy Commission (Industrial Chemistry—Extraction of Uranium from Leach Liquors)	15,866	15,866

A.—Includes adjustment of 1953-54 expenditure. An amount of £466 overdebited in 1954-55 will be adjusted in 1955-56.
B.—This expenditure relates to 1953-54.
C.—This expenditure relates to 1953-54.
D.—An amount of £5 overdebited will be adjusted in 1955-56.

	Receipts 1954-55 and balances brought forward from 1953-54.	Expenditure 1954-55.
	£	£
Department of the Navy (Marine Fouling Investigations—Division of Fisheries)	1,149 ..	1,057
Russell Pty. Ltd. (Crayfish Investigations—Division of Fisheries)	100 ..	..
Department of External Affairs (Handbook of Fish Fauna) ..	Cr. 29 ..	Cr. 29E
Crayfish Exporters Association of Australia (Crayfish Investigations—Division of Fisheries) ..	201 ..	..
Australian Cement Manufacturers (Cement Investigations—Industrial Chemistry)	1,500 ..	1,500
Apple and Pear Board—Thrips Investigations	62 ..	62
Committee for Dried Fruit Marketing (Division of Meteorological Physics	340 ..	328
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications)	24 ..	..
Wool Wax Report—Royalties ..	6 ..	..
Science and Industry Endowment Fund	2,704 ..	2,704
Miscellaneous Contributors (Mathematical Instruments Section) ..	126 ..	..
Miscellaneous Contributors (Mineragraphic Investigations) ..	513 ..	347F
Wool Scourers, Carbonizers, and Fellmongers Federation of Australia (Wool Textile Research) ..	3,000 ..	..
General Donations (Division of Building Research)	889 ..	..
Various Contributors (Foundry Sands Investigations—Division of Industrial Chemistry) ..	28 ..	..
Department of National Development — Kimberley Research Station	1,906 ..	1,906
Australian Dairy Produce Board (Dairy Research Laboratory) ..	10,000 ..	10,000
Australian Wine Board—Oenological Research	3,475 ..	3,090
Snowy Mountains Hydro-electric Authority (Cloud Investigations —Division of Radiophysics) ..	12,500 ..	..
Australian Dairy Produce Board—(Cheese Making Project—Dairy Research)	360 ..	360G
Department of Territories (Resources Survey—Papua and New Guinea)	12,916 ..	11,949
Department of National Development (Northern Australia Regional Survey)	18,915 ..	16,451H
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Textile Research)	6,023 ..	1,764
Various Contributors (International Wool Textile Research Conference)	50 ..	..
Australian Dairy Produce Board (Farm Mechanization Research)	500 ..	500
Joint Coal Board (Coal Investigations)	1,250 ..	..
George Aitken Pastoral Research Trust (Wildlife Survey Section)	1,300 ..	1,206
Special Revenue Fund—"Belmont" Field Station, Rockhampton (Animal Health and Production Investigations)	954 ..	954
Special Revenue Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations) ..	44,550 ..	32,639
Special Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations) ..	15,000 ..	..
Special Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations) ..	2,755 ..	1,492
Special Revenue Fund—Research Station, Griffith (Citricultural Investigations)	19,898 ..	8,817
	260,775 ..	181,650

E.—Adjustment of 1953-54 expenditure.
F.—This expenditure relates to 1953-54.
G.—Includes £172 which relates to 1953-54 expenditure.
H.—Includes £4 which relates to 1953-54 expenditure.

3. Wool Research Trust Account.

A credit balance of £559,935 was brought forward from 1953-54 in the Wool Research Trust Account. A further £432,228 was received during 1954-55, of which amount £388,675 was received from the Department of Commerce and Agriculture, the balance being proceeds of sale of produce. Complete details of transactions during 1954-55 are as follows:—

	£	£	£
Balance in Account, July 1, 1954 ..			559,935
Receipts 1954-55.			
Department of Commerce and Agriculture		388,675	
Revenue—			
Animal Health and Production—			
Cobram Field Station ..	3,072		
Regional Pastoral Laboratory, Armidale	12,899		
Sheep Biology Laboratory, Prospect	1,715		
Plant Industry—			
"Glen Lossie" Field Station, Kojonup	8,800		
Falkiner Memorial Field Station, Deniliquin ..	10,096		
Biochemistry and General Nutrition — "Glenthorne" Field Station	5,311		
Wool Textile Research Laboratories—			
Textile Laboratory, Geelong ..	1,585		
Biochemistry Laboratory, Melbourne	63		
Textile Laboratory, Sydney ..	12		
		43,553	
Total Receipts 1954-55 ..		..	432,228
			992,163
Expenditure 1954-55.			
Division of Animal Health and Production—			
Parkville—			
Sheep Physiology Investigations —Parkville	370		
Sheep Physiology Investigations —Tooradin	5,332		
Fodder Production—Cobram ..	3,459		
		9,161	
McMaster Laboratory—			
Parasitology Investigations— New South Wales	8,889		
Parasitology Investigations— Western Australia ..	500		
Dipping and External Parasites	1,143		
Biochemical Investigations ..	3,424		
Hollerith Equipment ..	2,954		
		16,910	
Yeerongpilly—			
Sheep Blowfly Investigations ..	1,528		
		1,528	
Sheep Biology Laboratory, Prospect—			
Administrative and General Expenses	57,822		
Fleece Analysis	7,184		
Wool Biology	42,626		
Strain Trial	9,431		
		117,063	
Armidale		.. 61,058	
National Field Statiton, "Gilruth Plains"—			
Animal Breeding and Strain Trial Investigations ..		.. 7,156	
McMaster Field Station—			
Wool Production and Sheep Breeding		.. 4,345	
Frodsley, Tasmania—			
Sheep Investigations ..		.. 905	
University of Queensland—			
Grant — Sheep Climatology Studies		.. 400	
			218,526
Division of Plant Industry—			
Agrostology Investigations ..		.. 96,658	
Research Services—			
Agricultural Research and Extension Liaison	4,739		
Wool Publications	17		
		4,756	

	£	£	£
Division of Industrial Chemistry—			
Expenditure on Wool Textile Research—			
Chemical Physics Investigations	10,164		
Organic Chemistry Investigations	13,184		
Physical Chemistry Investigations	2,921		
		26,269	
Division of Biochemistry and General Nutrition—			
Biochemical and Nutritional Investigations		37,994	
Wool Textile Research Laboratories—			
Wool Textile Research		231,125	
Wildlife Survey Section—			
Wildlife Survey		41,880	
Animal Genetics Section—			
Animal Genetics Investigations		13,917	
Miscellaneous—			
Overseas Studentships		2,918	
Total C.S.I.R.O. Investigations			674,043
Grants from Wool Research Trust Account to institutions undertaking research in agricultural economics relating to wool production—			
Department of Commerce and Agriculture—			
Bureau of Agricultural Economics	37,283		
Wool Adviser	1,895		
Total Department of Commerce and Agriculture Expenditure		39,178	
Total Expenditure 1954-55			713,221
Balance carried forward to 1955-56			278,042

4. Wool Industry Fund.

A credit balance of £1,096 was brought forward from 1953-54 in the Wool Industry Fund Account. A further £404,500 was received during 1954-55. Expenditure during 1954-55 amounting to £356,951 was incurred as follows:—

	£	£	£
Expenditure by C.S.I.R.O. Divisions and Sections.			
Biological Research—			
Animal Health and Production—			
Sheep Biology Laboratory, Prospect—			
Equipment for Climate Rooms	40,629		
Equipment	19,965		
Development expenditure—fencing, roads, water supply, &c.	8,439		
		69,033	
Regional Pastoral Laboratory and Chiswick Field Station, Armidale—			
Construction of small buildings and roads and provision of services	3,402		
Improvements	1,268		
		4,670	
Cobram Field Station—			
Permanent improvements—			
Hay shed	404		
		404	
Frodsley, Tasmania—			
Improvements	1,001		
Equipment	837		
		1,838	
			75,945

	£	£	£	£
Biochemistry and General Nutrition—				
Glenthorne Experimental Station—				
Sheep yards and units		2,612		
			2,612	
Plant Industry—				
Falkiner Memorial Field Station, Deniliquin—				
Developmental expenditure — fencing, water supply, irrigation, &c.		3,642		
"Glen Lossie" Field Station, Kojonup, Western Australia—				
Developmental expenditure—clearing, fencing, water supply, &c.		5,479	9,121	
Wool Textile Research—				
Biochemistry Laboratory, Melbourne—				
Plant		647		
Textile Laboratory, Geelong—				
Buildings and site	9,250			
Textile machinery	32,395			
Plant	6,637			
		48,282		
Physics and Engineering Unit, Sydney—				
Plant		4,281		
			53,210	
Electron Microscope		13,740		
				154,628
Expenditure by Department of Works on C.S.I.R.O. Buildings.				
Biological Research—				
Animal Health and Production—				
Sheep Biology Laboratory, Prospect—				
Animal house No. 2	1,335			
Two prefabricated buildings	3,936			
Animal house No. 1	8,493			
Main administrative building	84			
Climate controlled building	50,422			
Cottage No. 2	3,923			
Lunch and locker room	4,285			
Sheep incinerator	1,120			
Acquisition of land	1,900			
		75,498		
			75,498	
Plant Industry—				
Head-quarters, Agrostology Section, Canberra—				
Agrostology and Pasture Chemistry prefabrications		5,172		
Western Australian Investigations—				
Regional Laboratory, Perth	16,044			
Two staff cottages, Kojonup	1,148			
		17,192		
Regional Pastoral Laboratory and Falkiner Memorial Field Station, Deniliquin—				
Staff cottages	3,090			
Three cottages	2,409			
Bachelor quarters	822			
		6,321		
			28,685	
Biochemistry and General Nutrition—				
Glenthorne Experimental Station—				
Field Laboratory	4,693			
Hay and chaff shed	396			
		5,089		
			5,089	
Animal Genetics—				
Rabbit House—Prospect	2,534			
		2,534		
			2,534	

	£	£	£	£
Minor Works—				
New South Wales ..	4,092			
Victoria	1,699			
Western Australia ..	1,054			
Australian Capital Territory	357			
		7,202		
				7,202
Wool Textile Research—				
Biochemistry Laboratory, Melbourne—				
Laboratory building ..	30,480			
		30,480		
Textile Laboratory, Geelong—				
Laboratory and six cottages	3,693			
Development of site ..	1,720			
		5,413		
Textile Laboratory, Sydney—				
Laboratory bnilding ..	822			
Store building ..	2,048			
		2,870		
Minor Works—				
New South Wales ..	98			
Victoria	1,064			
		1,162		
				39,025
Grants from Wool Industry Fund for Extra-mural Co-operative Wool Research.				
Biological Projects—				
Victoria—				
Melbourne University—				
Electrolyte physiology studies	4,000			
Department of Lands and Survey—				
Rabbit investigations	3,210			
		7,210		
Western Australia—				
Institute of Agriculture—				
Ruminal flora studies	2,900			
Genetic studies ..	1,150			
		4,050		
South Australia—				
Roseworthy Agricultural College—				
Progeny testing ..	3,958			
Waite Institute—				
Agrostology, weeds, and entomology ..	3,888			
Department of Agriculture—				
Ovine brucellosis ..	2,500			
		10,346		
Queensland—				
Department of Agriculture and Stock—				
Fertility and neo-natal mortality	700			
Progeny testing and wool metrology ..	375			
Copper deficiency ..	350			
Poison Plants Committee	100			
Ovine brucellosis ..	550			
Alterations at Toorak Field Station ..	1,450			
University of Queensland—				
Sheep physiology ..	1,500			
Acclimatization studies	372			
		5,397		
New South Wales—				
University of Technology—				
Wool clip analysis ..	4,172			
University of Sydney—				
Animal physiology investigations ..	2,500			
Department of Agriculture—				
Disordered metabolism	1,185			
		7,857		
				34,800
Wool Textile Research—				
Gordon Institute of Technology—				
Wool Textile investigations	3,912			
Wool Industries Research Association, U.K. ..	1,254			
		5,166		
			5,166	
Additional Items Sponsored by C.S.I.R.O.—				
Expenses in connexion with Wool Textile Conference, 1955	3,364			
		3,364		
			3,364	
				356,951

5. Miscellaneous Receipts.

During 1954-55 miscellaneous receipts amounted to £89,543. Of this amount £23,269 represented proceeds of sales of equipment, publications, &c. The balance of £66,274 represented revenue earned by Divisions and Sections apart from the Special and Wool Revenue included under Sections 2 and 3 respectively. Details of the receipts are as follows:—

Revenue Receipts.

	£	£
Division of Animal Health and Production—		
Sale of Contagious Pleuropneumonia Vaccine	3,589	
Mastitis Investigations	4,378	
Parkville Laboratory	147	
Toxaemic Jaundice Investigations, Parkville, Victoria	239	
Oestrus Experiments	1,578	
Poultry Breeding Investigations ..	9,129	
Contagious Pleuropneumonia Investigations	3,909	
Tooradin Field Station	20	
Bacteriological Investigations	7	
Parasitological Investigations	263	
McMaster Field Station Revenue ..	3,876	
Veterinary Parasitology Laboratory ..	600	
Amberley Field Station, Queensland ..	430	
Genetics Investigations	7	
Division of Plant Industry—		
Plant Industry Investigations, Canberra ..	3,453	
Stanthorpe Field Station	510	
Samford Farm	45	
Division of Entomology—		
Entomological Investigations	507	
Division of Soils—		
Merbein Research Station, Revenue ..	3,852	
Soils Investigations	176	
Division of Food Preservation and Transport Revenue	405	
Division of Forest Products	192	
Ore-dressing Investigations	313	
Research Services—Film Unit	458	
Division of Industrial Chemistry—		
Industrial Chemistry Investigations ..	15,909	
Micro-analysis Investigations	3,419	
Division of Fisheries—		
Fisheries Investigations	258	
Sale of Pearlshell	1,448	
Division of Metrology	4,976	
Division of Electrotechnology	1,092	
Division of Physics	938	
Division of Building Research	23	
Division of Radiophysics	53	
Meteorological Physics Section	9	
Land Research and Regional Survey, Katherine	15	
Fuel Research Section	51	
		66,274
Other Receipts—		
Sales of publications	2,779	
Sales of equipment, &c.	20,490	
		23,269
		89,543

The above sum was paid to the credit of the Trust Fund Science and Industry Account during 1954-55 and consequently reduced the requirements from Treasury sources by that amount (*see* Section 1).

6. Works Projects (under Control of C.S.I.R.O.).

Expenditure on works projects financed from Treasury funds made available directly to C.S.I.R.O. is as follows:—

	£	£	£
Plant Industry—			
Beerwah Field Station—			
Developmental expenditure ..	2,455		
Stanthorpe Field Station—			
Refrigeration Chambers	1,643		
		4,098	
Industrial Chemistry—			
Fishermen's Bend Laboratory—			
Alterations to buildings	1,046		
Development of site	108		
		1,154	
Meteorological Physics—			
Aspendale Laboratory—			
Heating and ventilating unit ..	17		
Concrete work and power line ..	171		
		188	
Food Preservation—			
Laboratory, Homebush—			
Alterations and additions to Metropolitan Meat Industry Board buildings	3,445		
Contribution to cost of cold room ..	250		
		3,695	
Fuel Research—			
Coal Research, Ryde—			
Erection of coal bins; toilet and shower extensions	200		
		200	
			9,335

7. Miscelllaneous Services.

	£
Contribution to Commonwealth Agricultural Bureaux	49,252
Grant to Standards Association of Australia ..	42,000
Contribution to Chair of Aeronautics at University of Sydney (establishment and maintenance) ..	5,000
Grant to National Association of Testing Authorities	9,673
Australian and New Zealand Association for the Advancement of Science	1,300
Pan Indian Ocean Science Congress	2,400
	109,625

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.

18th October, 1955.

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