THE

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OF

NEW SOUTH WALES

FOR THE YEAR

1955

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WITH TWELVE PLATES.

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ANNUAL GENERAL MEETING.

30th March, 1955.

The Eightieth Annual General Meeting was held in the Hall of Science House, Gloucester Street, Sydney, on Wednesday, 30th March, 1955.

Dr. F. V. Mercer, President, occupied the chair.

The minutes of the Seventy-ninth Annual General Meeting, 31st March, 1954, were read and confirmed.

Presidential Address.

It is with mixed feelings that I deliever the eightieth Presidential Address of the Linnean Society of New South Wales. One part of me is elated at the privilege and honour of being, and continuing to be for another year, your President. Another part of me is depressed by the problems which face the Society in the future.

The Society came into being in 1874 to meet the scientific needs of the natural historians of that period. At that time scientific interests were concerned primarily with collecting and describing the fauna, flora and rock formations of what was a relatively recently discovered continent. There was a real need for an organization which would meet and foster this kind of interest. As a consequence the Linnean Society was founded "for the cultivation and study of Natural History in all its branches". Like a new species or organism in a favourable environment, and for much the same reasons, the Society, despite economic depressions and wars, flourished and fulfilled the needs which led to its formation.

Since about 1930 the membership of the Society has remained stationary, perhaps even falling during the last few years, and, if the attendance at the monthly meetings measures interests, then the Society would appear to be failing to maintain the interest of its members. Yet the scientific population of the community shows no such trend. A dozen reasons and platitudes could be given to account for these trends, but the one which seems to me to be the most important is the changing emphasis in the study of natural history. With almost frightening rapidity during the last decade or so the emphasis has shifted from the general to the specific. The specialist has replaced or is replacing the older type of natural historian. No longer are we classified as biologists or geologists, but we have become phytomorphologists, gene-ecologists or geophysicists and so on. What, then, is the role and purpose of a society such as this in an age of specialism? This Society, along with others of its kind in the world, must find a solution to the problem of specialization. Like an organism when the environment changes, a society must adapt to the new conditions or be eclipsed. To me the study of natural history is the study of evolution. Much of the specialization current in present-day biology arises from a difference between the descriptive approach to evolution as illustrated by Darwin's work, and the experimental approach of Mendel. Somehow this Society must achieve a synthesis between these approaches and provide a meeting ground between the systematist, the comparative morphologist, the comparative anatomist, the ecologist on the one hand and the geneticist, biochemist and physiologist on the other.

It is almost an axiom that financial crisis and scientific societies go together. No member of this society should assume from observing a credit of a few hundred pounds in the balance sheet that the financial state of the society is healthy. Let me mention a few facts. Once we were able to support four Linnean Macleay Fellows and a Linnean Macleay Bacteriologist; now there are two Fellows, and this year will see the end of the Bacteriologist. Falling returns from investments and the falling value of

money have made it impossible for the Society to maintain these positions. Since the income from the Bacteriology Fund is only sufficient to pay about half the salary of a bacteriologist, the Council, after considering various possibilities, decided to negotiate with the University of Sydney for the establishment of a joint appointment. Briefly, in the petition which will be submitted to Equity Court, the Society has offered the University of Sydney £700 p.a. towards the foundation of a "Linnean Macleay Lectureship in Microbiology". The University of Sydney has offered the remainder necessary to secure a first-class person. The Linnean Macleay Lecturer will enjoy the same status and privileges as an ordinary member of the University staff. The Society maintains some control over the lectureship, as the committee selecting the bacteriologist will comprise members of the University and the Linnean Society Council. It should be mentioned that Sir William Macleay bequeathed the Bacteriology Fund to the University. The University did not accept the conditions of the bequest, and it then reverted to the Linnean Society. It is expected that the first appointment to the lectureship will be made this year.

The apparent buoyant position of the Society has arisen only because we do not have a salaried secretary. Thanks entirely to the untiring, unselfish efforts of Dr. A. B. Walkom and Dr. W. R. Browne, the Society has been saved this expense. Our appreciation of the services of these two people cannot be too great. Society members should ask themselves the question "How will the Society manage if it has to finance a secretary?", and attempt to find the answer. Without being complacent, the past history of the Society is sufficient proof that we will find the solution to all our difficulties.

The total net return from the Society's one-third ownership of Science House for the year was £563. The Science House Extension Committee was disbanded during the year. An application by the Science House Management Committee to the Fair Rents Court for a determination of the rents of Science House will result in a substantial and very welcome increase of revenue to the Society. The Australian National Research Council surrendered its lease and became an ordinary tenant of Science House.

The Government grant to the Society to be made during the present financial year was increased to £200.

The Council decided during the year to publish three more cards of the Wildflower Series, thus making a set of five, as follows: No. 1, *Epacris longiflora* (The Native Fuchsia); No. 2, *Telopea speciosissima* (The Waratah); No. 3, *Boronia serrulata* (The Native Rose); No. 4, *Dillwynia ericifolia* (The Heath-leaved Dillwynia); and No. 5, *Lambertia formosa* (The Honey Flower).

Contrary to the impression which might be gained from the average attendance of 23, the monthly meetings were well attended. The low average was caused mainly by several poorly attended meetings held during the University vacations. The papers and exhibits covered a wide range of topics and the speakers presented their material in a form which proved interesting to even the most rabid specialist. In addition to the papers and exhibits presented, the following lecturettes of special interest were given at the monthly meetings:

May: "The Hair Growth in Animals", by Dr. A. S. Fraser, of the Animal Genetics Unit of C.S.I.R.O.

June: "The Cosmic Radiation", by Dr. A. J. Herz, of the Physics School, University.

July: "Let's Talk Turkey", by Dr. A. T. Hotchkiss, of the Botany School, University.

September: "The Biosynthesis of Rubber", by Dr. Adele Millard, former Linnean Macleay Fellow.

October: "Plants, Mountains and Laboratories", by Dr. Clark Ashby, Fulbright Fellow in Botany;

November: "Field Work in the New Guinea Highlands", by Ellis Troughton, illustrated by Kodachrome slides by Ederic Slater, A.R.P.S., clinical photographer at the Dental Hospital, Sydney.

We wish to thank and express our appreciation to all who contributed to these programmes.

During the year eight new members were added to the list, three members and an honorary member were lost by death, three have resigned, and four were removed from the list under Rule VII. The numerical strength of the Society at 15th March, 1955, was: Ordinary Members 204, Life Members 26, Corresponding Members 2, Associate Member 1; total 233. Professor J. L. Still resigned from the Council as from 23rd June, 1954, and Professor N. C. W. Beadle was elected in his place on 21st July, 1954.

The Eighth International Botanical Congress was held in Paris in July, 1954, and Miss N. Burbidge acted as the Society's delegate, later forwarding copies of some of the resolutions passed.

Parts 1–4 of Volume 79 of the Society's PROCEEDINGS were published in 1954 and Parts 5–6 in January, 1955; it consists of 246 + liv pages, 9 plates and 202 text-figures. Donations towards the cost of publication of papers were made by the University of Melbourne (for two papers) and Antarctic Division, Department of External Affairs, Melbourne. In future the three parts of the volume issued each year will be numbered Parts 1, 2 and 3 in place of the present practice.

Library accessions from scientific societies and institutions totalling 1,888 considerably exceeded the total for the previous year. Library loans, especially to the University of Sydney, C.S.I.R.O. and interstate institutions were requested as frequently as in past years. The number of subscribers to the PROCEEDINGS has again increased. A number of duplicate books in the Library were sold and reprints from the Society's stock were much in demand. All books and periodicals in the Library also were cleaned during August, 1954. Exchanges of publications for our PROCEEDINGS were commenced with the following: Croatian Society of Natural Sciences, Zagreb, Yugoslavia, and National Science Museum, Tokyo, Japan; and reprints from the PROCEEDINGS were offered to the Geological and Mineralogical Institute, Faculty of Science, Tokyo, University of Education, Tokyo, Japan (geological); Entomological Research Station, Cawthron Institute, Nelson, New Zealand (entomological); Geological Survey, Department of Lands, Mines and Survey, Suva, Fiji (geological) and New Zealand Oceanographic Institute, Wellington, New Zealand (marine biological).

In connection with the Society's representations concerning the exportation of type specimens of Australian flora and fauna a letter has been received from the Prime Minister's Department stating that the matter had been considered at the Australian Agricultural Council and the Standing Committee on Agriculture, and that the present arrangements are considered satisfactory.

Gosford District Fauna and Flora Protection Society held a conference on 12th February, 1955, at which the views of this Society were presented.

A party of biologists and geologists under the auspices of the Joint Scientific Advisory Committee (comprising members appointed by the Linnean Society of New South Wales and the Royal Zoological Society of New South Wales) made a sixth and very successful trip to the Kosciusko area from the 13th to the 27th January, 1955. Transport and accommodation were provided by the Department of Botany, University of Sydney, and the Department of Tourist Activities and Immigration, N.S.W.

Congratulations and best wishes were conveyed to the newly-formed Australian Academy of Science, assuring the Academy of the Linnean Society's readiness to co-operate with it in advancing the cause of science. I wish to offer congratulations to Professor W. L. Waterhouse on the honour conferred upon him (Companion of the Order of St. Michael and St. George) by Her Majesty the Queen; to Professor J. M. Vincent on his appointment to the Associate Chair of Agricultural Microbiology; and to Professor I. A. Watson on his appointment to the Associate Chair of Genetics in the Faculty of Agriculture.

Linnean Macleay Fellowships.

In November, 1953, the Council appointed Miss Nola J. Hannon and Miss Ruth Simons to Fellowships in Botany for 1954.

Miss Hannon, during 1954, continued her work on the status of nitrogen in the Hawkesbury Sandstone communities of the Sydney district. The following were the

main lines of investigations: (1) *Non-symbiotic N-fixing microorganisms.* Soil samples were incubated under suitable conditions of moisture and temperature, from serral stages of a psammosere, and shrub swamp and dry sclerophyll forest climax communities. Incubation was made under both aerobic and anaerobic conditions, and treatments containing addition of a carbon source and mineral nutrients other than nitrogen were included. This work has demonstrated the presence of both *Azotobacter* and *Clostridium* strains, which are capable of nitrogen fixation, where the pH is above neutrality. The strain of *Azotobacter* proved to have interesting characteristics, and work on its physiology is continuing in collaboration with Dr. Tchan, Macleay Bacteriologist. Where calcium carbonate is not present and the soil pH is about 6·0–7·0, *Azotobacter* was not found, but *Clostridium* remained active. In the acidic soils of pH 4·5–5·0, neither *Azotobacter* nor *Clostridium* was found. Loss through denitrification also occurred in the psammosere samples, but not in the climax communities. These samples were also incubated under light conditions and nitrogen-fixing blue-green algae of the Nostoc–Anabaena group were found in the beach sands. Algal growth in the climax communities is under investigation at the moment. (2) *Preliminary examination of the crustaceous lichens.* The lichens are prominent in the early stages of the lithosere and the three most common members, *Rhinodina*, *Buellia* and *Parmelia*, were chosen for study. Young colonies were tagged in the field and others brought into the glasshouse, where they were given a constant water supply and various mineral nutrient treatments. Over a period of eight months no significant growth was recorded in any of the treatments. (3) *Analysis of rain and drainage waters.* Ion-exchange resin columns were set up in the field and were used to concentrate the nitrate, nitrite and ammonia content of the rain and drainage waters passing through them. The columns were subsequently eluted and analysed in the laboratory. This has shown that over the greater portion of the year nitrate and nitrite were not detectable in the rain water, but ammonia was present in appreciable quantities. Drainage water analysis has shown that significant quantities of ammonia are lost from the ridges.

Miss Simons was granted leave of absence till 8th February, 1954. She was married on 13th March, becoming Mrs. Leonard Martin, and resigned her Fellowship as from 6th August, 1954. A summary of her work during the tenure of a Fellowship is as follows. Further identification of fungi isolated from *Casuarina suberosa* litter was carried out. Experiments were begun using artificial leaching, to enable an estimation to be made of the amounts of various constituents of the litter removed by falls of rain and carried into the soil. Analyses of the leachate showed that only a small percentage of both organic and inorganic fractions in the several layers of the litter is available for removal by rain. The amounts of the individual constituents lost varied considerably from layer to layer. The difference may be correlated with differences in physical condition and biological population between layers.

In November, 1954, the Council reappointed Miss Nola J. Hannon and appointed Miss Mary B. MacDonald to Fellowships in Botany for 1955.

Miss Hannon proposes to undertake a detailed investigation into one aspect of nitrogen fixation in native legumes, in addition to her work on the physiology and nitrogen fixation mechanism of *Azotobacter*. This latter study arose as a result of the isolation of a strain of *Azotobacter* capable of survival under anaerobic conditions, from the beach sands in the Hawkesbury Sandstone sand-dune succession.

Miss MacDonald was given permission to take part in a Natural History expedition to Kosciusko during January, 1955. She proposes (1) to attempt to complete a revision of descriptions of the species of the genera of the family Characeae in New South Wales; (2) to determine chromosome numbers of other species, and from this information to construct a phylogenetic series within the Characeae of New South Wales; (3) to attempt cross-breeding experiments in dioecious species to confirm evidence of relationship from the chromosome number; and (4) to study variation in culture, and its bearing on accepted taxonomic categories.

We wish both Fellows success in their research work.

Macleay Bacteriologist.

During the year 1954–55 Council again granted permission for Dr. Yao-tseng Tchan to deliver lectures to advanced students in Agricultural Microbiology at the University of Sydney. In February, 1955, Dr. Tchan transferred from the Department of Botany to the Microbiological section of the Faculty of Agriculture of the University of Sydney, and permission was granted by the Council for him to do part-time work in that Faculty as from the middle of February, 1955. His work on the semi-arid soil is partly finished. Two papers, in collaboration with Professor N. C. W. Beadle, are ready for publication. The general conclusion of the results is that the amount of N fixed through bacteria and algae is small—a maximum of 2–3 pounds per acre per annum. However, if no loss occurs, it would be significant over long periods. The chemical analysis and bioassays of these soils (about 50 samples tested) showed that the limiting factor of plant growth in these soils is N if the water supply is non-limiting. No significant deficiency of P or Cu is recorded. It is logical for future studies in this region to concentrate on the N-economy of the soil through other biological processes (e.g. symbiotic N-fixation, denitrification and soil respiration). The study of a new technique of estimating soil protozoa with J. Burit is finished. A preliminary note has been published in *Nature*. The detailed paper will shortly be submitted for publication. Cytological investigations of *Azotobacter* have been continued. For his future research programme Dr. Tchan proposes to continue investigations on semi-arid soils and on soils of the Northern Territory, the latter in collaboration with C.S.I.R.O. (Land Research and Survey Section). More detailed work will be done on the estimation of soil fertility by microorganisms, and cytological and ecological investigations on N-fixing bacteria.

Obituaries.

It is recorded with regret that the following members and honorary member died during the year:

Mr. Kenneth George Brown, B.Sc., who was elected a member of the Society on 26th April, 1950, died on 7th April, 1954. On 30th July, 1952, he delivered a lecturette to the Society, illustrated by a film and exhibits, on the Natural History of Heard Island. He was biologist to the Australian Antarctic Expedition, 1951.

Mr. Wilfred Alexander Watt de Beuzeville, J.P., of Beecroft, N.S.W., who died on 28th March, 1954, had been a member of the Society since 1925. He contributed one paper (with Mr. C. T. White) to the Society's Proceedings in 1946. He was born at Bombala, N.S.W., where his father managed a group of stations, in 1884. In 1911 he joined the staff of the N.S.W. Forestry Department and was engaged on forest survey and assessment work until 1919, when he was placed in charge of the Forestry District extending approximately from Goulburn to the Victorian border, with headquarters at Tumut. During the next ten years he organized the establishment of about eight or ten large pine plantations in the district, in addition to the development of the natural forests in the area, especially the Alpine Ash forests at Batlow. From about 1930 to 1935 his services were made available to the C.S.I.R. Forest Products Division, and he collected botanical data from all parts of the eastern States. During the balance of his service with the Commission he was engaged in research work and established the experimental forest and nursery at Pennant Hills. It was during this period that he compiled his Climatic Index of the World, which required the analysis of rainfall and temperature statistics from each country. During the last years of his service as Forest Ecologist he wrote a number of pamphlets and finally the book "Australian Trees for Australian Planting", which was published in 1953. For more than forty years Mr. de Beuzeville preached the doctrine of soil conservation, and in his later years carried out a number of investigations for the Department, especially in the far west of the State. He was always a keen botanist and for many years corresponded regularly with the late J. H. Maiden. He described several new species of Eucalypts, sometimes working in collaboration with his friend the late M. B. Welch. Following his retirement Mr. de Beuzeville spent about a year in England and on the Continent,

returning to Sydney in 1951. During the next twelve months he was employed by the Food and Agriculture Organization of the United Nations, selecting lists of Australian trees suitable for reafforestation in Ethiopia and Syria. In February, 1953, he suffered a severe heart attack which left him an invalid until his death.

Mr. Ernest Godfried Jacobs, who had been a member of the Society since 1917, died on 10th July, 1954. For a number of years he was a regular attendant at monthly meetings. Mr. Jacobs was Headmaster of Christ Church Schools (Pitt Street, Sydney) for thirty-three years. He completed a course of training at Sydney Technical College for the Associate Diploma in Biology, which he gained, with honours, in February, 1912. During the absence in 1913–14 of Dr. S. J. Johnston in Europe he was Temporary Assistant Teacher of Botany at the Sydney Technical College, and in 1917 and 1918 was Permanent Assistant Teacher of Botany. Mr. Jacobs was always an interested and active member of the Workers' Educational Association Ramblers' and Naturalists' Club and for a number of years prior to his death was their president. Members of this Club planted a tree (*Melaleuca leucadendron*) to his memory at the W.E.A. Summer School, Newport, N.S.W., in November, 1954. His knowledge and skill in botany and allied sciences had gained the highest respect of all who knew him. He was a regular churchman and keenly interested in theology.

An Honorary Member of the Society since 1923, Professor James Peter Hill, D.Sc., F.R.S., died suddenly at his home in London on 24th May, 1954, in his eighty-first year. He came from Edinburgh to become demonstrator in biology at the University of Sydney in 1892, and in 1904 was lecturer in embryology. Professor Hill was a member of the Society from 1893 and a member of Council from 1901–1906. He published eleven papers in the Society's Proceedings between 1893 and 1900, including one as joint author with Professor W. A. Haswell and one with Professor C. J. Martin. He returned to England in 1906 and was Professor of Embryology at London University from 1921 to 1938, when he retired at the age of 65. He was elected to the Royal Society in 1913 and awarded the Darwin Medal in 1940. A more detailed account of his career, work and personality is given in *Nature*, Vol. 174, No. 4429, p. 109, July 17, 1954.

The Water Relations of Plant Cells.

(Plate A; Text-figures 1–3.)

I have chosen as the topic for the Presidential Address "The Water Relations of Plant Cells". I have made this choice for several reasons. First, because at the present time it is one of the controversial issues in botany; secondly, because drought is one of the major factors controlling the development of agriculture in Australia; and thirdly, because it is a subject which interests various members of the staff of the Botany Department at the University.

For approximately the last seventy years botanists have believed that osmosis was the mechanism underlying the water relations of plant cells. Before 1880 the process controlling the water relations of cells was only vaguely understood. Within ten years following the publication in 1887 of Pfeffer's results on the osmotic properties of plant cells and solutions, the osmotic theory of the cell was firmly accepted. Almost any botanist between 1890 and 1936, if asked to state one truism in botany, would probably have said "all mature plant cells are osmometers". Every student during the same period was convinced of the validity of the theory as he or she watched the curling of a dandelion stalk in water. (Even to-day the same experiment is used to demonstrate the theory to first-year students.) Every housewife, not that she realized it, who placed cut stalks of celery in water and saw them curl, was bearing witness to the osmotic theory.

By the turn of the century the theory was to be found in almost all text-books. At that time it was referred to simply as the Osmotic Theory. Later, because of the respectability gained from years of standing, the theory had become the Classical Osmotic Theory. Although it did not explain all the facts known about the water relations of cells, it was generally believed that such facts would eventually fall into place

within the framework of the theory. Moreover, as it is a generalization about the nature of the plant cell, the theory has formed the basis of much fundamental research, not only in water relations, but in many fields of plant physiology. It has provided, for example, the theoretical stimulus for studies on permeability, translocation and cellular organization. However, by the forties of the present century the number of observations concerned with the water relations of cells which were apparently contrary to the "Osmotic Theory" had increased to such an extent that their significance could no longer be overlooked. Many plant physiologists came to doubt the validity of the Osmotic Theory. An alternative theory, the theory of Active Water Uptake, was proposed to explain the apparently anomalous water relations of some plant cells.

This address is an attempt to assess the relative importance and validity of the two theories. Unfortunately, time will not permit a detailed analysis of all the experimental evidence and theoretical arguments which led to the Active Uptake Theory. Only some of the more important so-called "anomalous" data will be examined. This limitation, however, does not lessen the value of the conclusions reached.

At this point it should be mentioned that the Osmotic Theory refers ideally to the mature vacuolated cell. Quite early in the studies of cell water relations two extreme types of cell were recognized (excluding the highly specialized cells such as phloem and xylem): one, the mature, highly vacuolated parenchyma type, characterized by a large central vacuole occupying at least ninety per cent of the total cell volume, enclosed by a very thin layer of cytoplasm and a thin cell wall; the other extreme, the meristematic cell, characterized by dense cytoplasm and the absence of conspicuous vacuoles. Between these types a complete range of cells with varying ratios of cytoplasm:vacuole exist. The pioneer investigators realized that the water relations of the extreme types were not exactly comparable. With meristematic cells it was recognized that the problem was essentially the water relations of cytoplasm, whereas with the mature cell the problem was essentially the water relations of the vacuole. The Osmotic Theory was developed from a study of the water relations of highly vacuolated cells and, strictly speaking, refers in its simple form to the vacuolated cell only. Many of the criticisms of the Osmotic Theory prior to 1936 were concerned with differences between the meristematic and vacuolated cell types. On the other hand, however, most of the recent criticisms of the Osmotic Theory have arisen from studies on mature cells. This fact simplifies our discussion, since the experimental work supporting both the Osmotic and the Active Uptake Theories has been obtained with essentially the same type of cell.

The Osmotic Theory.

According to this theory, a mature plant cell functions like a simple osmometer enclosed by a more or less elastic wall. The vacuolar sap corresponds to the solution phase, the protoplasm or protoplasmic membranes to the semi-permeable membrane, and the cell wall to the more or less elastic wall. The water relations of such a system are defined by the equation

$$DPD = (OPv - OPe) - TP$$

where DPD is the diffusion pressure deficit, OPv and OPe the osmotic pressure of the vacuolar sap and the environment, TP the turgor pressure. Although the movement of water is determined by the direction of the diffusion pressure gradients, the mechanism responsible is osmotic in origin. The protoplasm and the protoplasmic membranes are assumed to play no role, other than that of a passive sieve, allowing the free diffusion of water, but not of solute. It is realized that the above equation is a simplification, in that the distinction between turgor pressure and wall pressure is not made.

The Active Uptake Theory.

The Active Uptake Theory has resulted from the many observations which claim to show that the diffusion pressure deficit is larger than can be expected from the osmotic pressure of the vacuolar sap. This has led to the idea that the diffusion pressure

deficit is due in part to a non-osmotic component as well as an osmotic component. A fraction of the water is assumed to be held in the vacuole by the secretory activity of the protoplasm or the protoplasmic membranes. The equation defining the water relations of the cell has been modified as

$$DPD = (OPv + X - OPe) - TP$$

where DPD, OPv, OPe and TP have the same meaning as before, and X is the non-osmotic or "active uptake component". As the non-osmotic component apparently opposes a diffusion gradient, energy released during respiration is assumed to maintain the state of osmotic non-equilibrium.

As may be seen from this brief comparison, the two theories have one process in common, namely osmosis. They differ in that the Osmotic Theory assumes that the cytoplasm and membranes function only as sieves, whereas the Active Uptake Theory assumes that these structures have a specific function towards water molecules, causing a movement of water independently of osmosis.

The Experimental Basis of Osmotic Theory.

Before discussing the data which have led to the Active Uptake Theory, it is informative to examine some of the experimental results obtained by Pfeffer, de Vries, Fitting, and Overton (see Lucke and McCutcheon, 1932), which form the basis of the Osmotic Theory. As much of this evidence is available in text-books, only the main points will be mentioned. These will suffice to demonstrate the strength of the arguments on which the Osmotic Theory is based. In fact, we shall see there are plenty of examples of cells behaving as almost ideal osmometers.

Pfeffer, whose pioneering research produced the stimulus for the early work on osmosis, became interested in the problem of water relations while experimenting on the mechanism of leaf movement in the sensitive plant. He noticed that certain cells of the pulvinus decreased in volume during movement, at the same time exuding water into the intercellular spaces. After a time lag the cells reabsorbed the water, returning to the original volume, and the leaves returned to their original position. By stretching the contracted tissue, the force necessary to bring about leaf movement was estimated to be from two to four atmospheres. The fact that the cells of the pulvinus underwent large reversible volume changes in which a force of several atmospheres was involved, suggested to Pfeffer that the mechanism might be similar to that occurring in an osmometer. As with the osmometer, the force exerted under tension would be equal to the force causing the movement of water into the cells. Using a Traube type osmometer, Pfeffer determined the quantitative relation between the force causing water to move into the osmometer, that is, the osmotic pressure, and the concentration and the temperature of the solutions.

Following the publication of Pfeffer's results for the osmotic pressure of solutions, van't Hoff formulated his theory of solutions and pointed out the similarities between the Gas Laws and the Laws of Osmosis. This was an important step forward, because it provided the means for testing quantitatively the analogy between the osmometer and the plant cell suggested by Pfeffer. Botanists were now in a position to examine experimentally a definite theory. If the theory were true, certain predictions could be made about the behaviour of cells when placed in solutions. Actually four theoretical propositions were defined.

First, it was argued that if the plant cell functions as an osmometer, then its volume should be the same in all solutions having the same osmotic pressure; or in another form, all solutions isotonic with the cell must have the same concentrations. De Vries used the phenomenon of plasmolysis as a means of estimating the isotonicity of the solutions and the relative osmotic pressure of cells. It was argued that at the point of incipient plasmolysis the concentration of the cell sap must be equivalent to the concentration of the plasmolyticum. The mature vacuolated cells of *Curcuma rubucanales*, *Tradescantia discolor* and *Begonia manicuta* were used as the test osmometers. For non-electrolytes like sucrose and dextrose, the theoretical prediction held, but solutions of electrolytes were found to be isotonic at lower concentrations.

For equivalent concentrations electrolytes were more effective than non-electrolytes. It was clear, however, that towards certain solutions the cells behaved almost as perfect osmotic systems. The discrepancies observed between non-electrolytes and electrolytes were realized by de Vries to be due to differences between the solutions rather than to a property of the cells. To compare the osmotic activity of different solutions, he introduced the term isotonic coefficient i, which is the ratio of the osmotic activity of solutions using as a standard a value of 3 for KNO_3. The fact that solutions have different isotonic coefficients was used as the second argument for testing the hypothesis that plant cells function like osmometers. If the theory were true, then the value of the isotonic coefficient determined plasmolytically should be identical with the value calculated from the freezing point or the conductivity of the solutions. In Table 1 are given some values obtained for *Rhoeo discolor* cells by Fitting.

TABLE 1.

Solution.	Value of *i* Calculated from		
	Plasmolysis.	Cryoscopic.	Conductivity.
KNO_3	1·69	1·78	1·83
KCl	1·74	1·84	1·86
$MgSO_4$	1·05	1·1	1·33
$Mg(NO_3)_2$	2·54	2·55	2·43
$BaCl_2$	2·42	2·46	2·41
$MgCl_2$	2·49	2·64	2·45

The general agreement between the values strongly supports the Osmotic Theory. The discrepancies were interpreted as due to the penetration of solute into the cells. Any plasmolytic method has a disadvantage in that the external solution may have an injurious effect on the living cell, and so cause departures from ideality. But despite the deviations from expectation, the agreement between the values indicates that some cells at any rate obey the van't Hoff Laws.

The third argument used to test the hypothesis was that if cells are osmometers, then it should be possible to use them for estimating the molecular weights of compounds, since isosmotic solutions should contain the same number of molecules. Striking confirmation was obtained by de Vries, who used cells of *Tradescantia discolor* for estimating the molecular weight of raffinose. Several possible values, 396, 594 or 1188, had been proposed. By estimating the concentration of raffinose and sucrose isotonic with these cells, de Vries calculated a value of 595·7 for the molecular weight of raffinose. Subsequently, chemical methods gave the value of 594·3.

Conversely, if plant cells function as osmometers, it should be possible to calculate from the molecular weights the concentrations of solutions isotonic with the cell and with a known sucrose solution. In Table 2 are results obtained by Overton for *Spirogyra* cells.

Again the agreement between the observed and calculated values strongly supports the Osmotic Theory.

The experimental findings of de Vries, Pfeffer, Fitting and Overton, which have been mentioned, clearly demonstrate that some plant cells obey the van't Hoff Law. With certain species the agreement was almost perfect. In others, deviations from ideality were observed. These anomalies were attributed to the penetration of solutes into the cells, to toxic effect of the solutes on the cells, or to errors in the methods. In all instances, whether the agreement was almost perfect or whether larger deviations from ideality occurred, the results appeared to prove that the process controlling the water relations of plasmolysed cells was osmosis, arising from the osmotic pressure of the cell sap. It should be stressed that the results referred to plasmolysed mature

vacuolated cells, that is to cells in which the cell wall can be neglected. The initial evidence on which the simple Osmotic Theory was first based refers to mature, highly vacuolated cells in a particular state, plasmolysis.

TABLE 2.

Compound.	MW.	Isosmotic Concentration.	
		Observed Percentage.	Calculated Percentage.
Sucrose	342	6·0	—
Mannitol	182	3·5	3·2
Dextrose	180	3·3	3·2
Arabinose	150	2·7	2·6
Erythritol	122	2·3	2·1
Asparagine	132	2·5	2·3
Glycine	75	1·3	1·3

When attempts were made to apply the van't Hoff Law to turgid cells, serious anomalies were observed. Between incipient plasmolysis and full turgor the volume of the cell was smaller than that expected from the osmotic pressure of the cell sap. That the cell wall influenced in some way the volume of the cell had been realized ever since Nageli (1850) described plasmolysis. It was not until much later that a clear picture of the role of the wall in water relations was obtained by Ursprung and Blum, Thoday, Höfler, and others. Their work showed that, as the cell absorbed water, turgor increased due to the opposing force which the cell exerted on the cell contents. The pressure due to the cell wall opposed the osmotic pressure of the cell contents. Hence it was concluded that the property of the cell controlling water relations between incipient plasmolysis and full turgor is not the osmotic pressure, but the difference between the osmotic pressure and the turgor pressure. This quantity has been described by various terms, suction pressure, suction force, water absorbing power, diffusion pressure deficit, net osmotic pressure. In this address, following the suggestions of Meyer (1945), diffusion pressure deficit (DPD) is used.

Since turgor opposed the osmotic pressure, the latter cannot be fully effective in causing water movement and volume changes. As a consequence, deviations from the van't Hoff Law must result. The departures from ideality seen with turgid cells, which at first sight appear to be contrary to the Osmotic Theory, have been accounted for by the turgor pressure. The general relationship between the three variables, the diffusion pressure deficit, the osmotic pressure of the cell sap and the turgor pressure, is given by the equation

$$DPD = (OPv - OPe) - TP$$

where DPD is the diffusion pressure deficit, OPv and OPe the osmotic pressure of the cell sap and the external environment, and TP the turgor pressure.

The equation is applicable irrespective of the exact relationship between turgor and cell volume—a relationship which can be expected to vary according to the elasticity and tensile strength of the cell walls. For some cells the relationship is known to be linear, for others it is more complex. The introduction of a turgor pressure term does not alter the basic concept of the cell as an osmotic system. In fact, the equation is also the equation of an ideal osmometer enclosed by a more or less rigid wall.

Despite the fact that the role of the wall and turgor pressure were recognized by 1920, little effort was made to test the validity of the modified Osmotic Theory experimentally. This oversight can be appreciated because the work of de Vries, Pfeffer and others had shown that many adult cells in the plasmolysed state obey the

van't Hoff Law. Consequently, there were no *a priori* reasons for assuming that processes other than osmosis and turgor would operate in the turgid cells. Most of the experimental work was directed towards establishing the exact relationships between the volume of the cell and the turgor pressure. Such questions as whether turgor is a linear function of volume or not occupied the interests of botanists. The experimental work was not designed to examine the exact nature of the processes contributing to the diffusion pressure deficit. In fact, this appeared to be unnecessary, for it seemed clear that only osmosis and turgor were concerned; that the diffusion pressure term may contain a non-osmotic component was not envisaged.

After 1920 the only important modifications (other than the active uptake hypothesis) to the theory was the realization that the cell is a dynamic, not a static, system—a dynamic system in which both the osmotic pressure and the turgor pressure and the permeability may fluctuate with time and with the metabolic action of the cell. Also the idea of semipermeability was replaced by one of differential permeability. These modifications, however, have not altered the fundamental concept, that the osmotic pressure of the vacuolar sap, and the turgor pressure of the wall are the only factors controlling directly the water relations of a mature cell.

In 1936, following the publication of a paper by Bennet-Clark, Greenwood and Barker, in which the plasmolytic and cryoscopic methods of measuring the osmotic pressure of the vacuolar sap were compared, the subject was reopened. To-day it is one of the controversial issues in plant physiology.

The Evidence for the Active Uptake Theory.

The evidence supporting the "Active Uptake Theory" has come from several different lines of argument. How this evidence appears to contradict the Osmotic Theory may be seen by examining the relationships which might be expected to hold if the Osmotic Theory is correct. We have seen that the Osmotic Theory may be summarized by the equation DPD = (OPv – OPe) – TP. If this is true, then the following relationships are to be expected.

1. When TP = O, i.e. cells in the state of plasmolysis:

(*a*) OPv = OPe, i.e. the osmotic pressure of the vacuolar sap should equal the osmotic pressure of the external plasmolysing solution. This is the theoretical basis of the plasmolytic method of measuring the osmotic pressure of the vacuolar sap. In the plasmolytic method cells are immersed in solutions of varying concentration, and the osmotic pressure of the solution causing incipient plasmolysis is taken as the osmotic value of the vacuolar sap. Furthermore, the value of the osmotic pressure of the vacuolar sap should be the same no matter how it is measured. In particular, the plasmolytic value should be the same as the cryoscopic value. The latter is the value estimated from the freezing point of the cell sap.

(*b*) The volume of the vacuole should be proportional to the reciprocal of the osmotic pressure (1/OPe) of the external solution, and be the same in all non-toxic, non-penetrating solutions.

2. In fully turgid cells, where OPv = TP and DPD = O:

(*a*) Assuming that OPe and TP do not alter, the volume of the vacuole should remain constant with time.

(*b*) The water relations of the vacuole should show the characteristics of a physical, not those of a chemical or metabolic process.

Many observations are known which suggest that for certain tissues these relationships do not apparently hold. In almost every instance the discrepancies between the results observed and those expected suggested that the diffusion pressure deficit was larger than could be expected from the osmotic pressure of the cell sap. For this reason many plant physiologists believe that an energy requiring secretory process in addition to osmosis plays a role in cell water relations.

Some idea of the present controversial nature of the problem of cell water relations can be gauged from the fact that some of the above arguments are identical with those employed by de Vries, Pfeffer and others to establish the Osmotic Theory. In fact, numerous results, of which a few were mentioned earlier in this address, show that many cells obey almost exactly the Boyle van't Hoff Laws. Yet I have just mentioned that more recent work has led to a different conclusion. How can these opposing views be resolved? This question has interested quite a few members of the Botany Department, some of whom are also members of this Society.

In this address, because time is too short, it will not be possible to examine in detail all the evidence which appears contrary to the Osmotic Theory. My analysis of the problem will be limited to a few of the more striking anomalies chosen from the arguments 1 (*a*) and (*b*) to 2 (*a*) and (*b*), outlined previously.

1. (*a*) *The discrepancy between the plasmolytic and cryoscopic values of the vacuolar sap.*

As mentioned previously, the paper by Bennet-Clark, Greenwood and Barker (1936), which triggered the present controversy, dealt with a comparison between the plasmolytic and cryoscopic methods of measuring the osmotic pressure of the vacuolar sap. According to the arguments already outlined, the plasmolytic and cryoscopic values should be identical, if the Osmotic Theory is correct. For several different plants the plasmolytic value was found to be from 2·2 to 7·1 atmospheres greater than the cryoscopic value. To account for this discrepancy, Bennet-Clark *et al.* suggested that the cryoscopic value, since it was determined on sap expressed under pressure from the tissues, measured the osmotic pressure, OPv, of the vacuolar sap, while the plasmolytic value, since it was determined on living cells, measured the total water-absorbing power of the tissue. The latter quantity would include all processes concerned with the uptake of water. They attributed the difference between the two values to a non-osmotic secretory component, X, so that the plasmolytic value was assumed to be a measure of OPv + X.

Subsquently, other investigators confirmed the observations of Bennet-Clark *et al.* on different tissues. Although the existence of a discrepancy between the two values has been confirmed many times, there is no general agreement on the explanation. Nor is the plasmolytic value invariably greater than the cryoscopic.

There is no *a priori* reason for assuming that the discrepancies must be due to the same cause in the different experiments. It is possible that the explanations suggested by the various authors may be the true explanation for the particular experiment described. Actually the crux of the problem depends on the validity of the assumptions that both methods have a high degree of accuracy, and that the expressed sap used for the cryoscopic measurements is pure vacuolar sap. There is a mass of evidence demonstrating that both methods are beset with errors, and that the expressed sap used in cryoscopy is not pure vacuolar sap (Crafts, Currier and Stocking, 1949).

Let us look at some of these errors. In the techniques of sap extraction, either a small mass of living material or a mass of tissue previously killed in liquid air or some other agent is wrapped in cheesecloth and pressed. The liquid, which is expressed under high, rapidly applied pressures, is taken to be pure vacuolar sap.

Mason and Phillis (1939) and Bennet-Clark *et al.* (1936) claim that high, rapidly applied pressures rupture the cell membranes or cause fissures to develop through which pure vacuolar sap escapes. The main argument used to support this view is the relationship observed between the concentration of the expressed sap and the applied pressures. Small, slowly applied pressures yield a dilute sap, whereas a high, rapidly applied pressure suddenly yields a concentrated sap. Low pressures, so it is argued, do not destroy the permeability properties of the tonoplast and cell membrane; consequently filtration of the expressed sap occurs. The low cryoscopic values always observed with low pressures are consistent with this argument. High pressures, suddenly applied, are assumed to destroy the permeability properties of the membrane, and so allow pure sap to escape. Hence the high cryoscopic value which is suddenly obtained with high pressures. This assumption overlooks the possibility of the cytoplasm being

disorganized by high pressures. If disorganization occurs, the possibility of contamination of the vacuolar sap by cytoplasmic materials must exist. Since there are no sound reasons for neglecting this possibility, it becomes of some importance to speculate on the possible effects of high pressures on the distribution of water between the components of the disorganized cell. Presumably, in a living tissue at equilibrium with its environment, the activity of the water in the vacuole, cytoplasm, and cell walls must be equal. If the Osmotic Theory is correct, the activity of the water in the vacuole is determined by the concentration of the solutes present, whereas, in the cytoplasm and wall, because of the presence of colloidal materials, the activity of the water would be due to imbibitional forces as well as to any freely diffusible solutes present. Van der Waal forces, hydrogen bonds, dipoles and ions held electrostatically to charges attached to colloidal components are taken collectively as imbibitional forces. Further, the activity of the water in all phases of the cell is influenced by the hydrostatic pressure of the cell contents.

In such a system, when pressure is applied, movement of water will not occur until the applied pressure equals the hydrostatic pressure. Thereafter, provided the pressure does not disorganize the cell membranes or the cytoplasm, the activity of the water in each phase of the cell will be insufficient to maintain the initial water content, and pure water must exude from the tissue. The fact that low pressures are known to yield almost pure water supports this contention.

With high pressures the situation is likely to be different. Since the plasmolytic-cryoscopic discrepancies have been observed with sap extracted from both living and tissue killed in liquid air, etc., before the application of pressure, it seems reasonable to assume that filtration of solutes from the vacuolar sap by the cell membranes is not a main factor contributing to the difference. Also, certainly with killed tissue and most probably with the living disorganized tissue, it is difficult to escape the conclusion that sap extracted under high pressures must be a mixture of cytoplasmic, vacuolar and wall fluids. We have seen that before the application of high pressures and before killing the water in the vacuole is associated with diffusible solutes and is in equilibrium with the water in the wall and cytoplasm which is held partly by imbibitional forces. Hence in the killed or disorganized cells mass some of the water will be associated with "free" solutes and the rest will be held by imbibitional forces but the relative distribution may not be the same. Is it reasonable to assume that the concentration and composition of sap expressed under pressure will remain identical with that of the vacuolar sap of the living tissue?

Actually, many indirect arguments can be stated to the contrary. For instance, in vacuolar sap containing organic acids or other solutes capable of undergoing dissociation, changes in the hydrogen ion concentration would alter the degree of dissociation, and so alter the freezing point of the sap. That changes in the pH of the vacuolar sap may occur cannot be rejected, since there is evidence that the vacuolar solution and the cytoplasm in the living state are at different pH's. Also, exposure to atmospheric oxygen and carbon dioxide and autolysis changes can be expected to alter the pH of the mixed fluids. Changes caused in this way could either increase or decrease the freezing point of the expressed sap, depending on the direction of the pH change.

Another factor which could alter the freezing point of the expressed sap would be changes in the electrostatic properties of the cytoplasmic and wall colloids and therefore changes in their imbibitional properties. If death or disorganization does not alter the total number of electrostatic charges, hydrogen bonds and so on, the fraction of water held by these imbibitional forces in the living tissue would be expressed under pressure as almost pure water. The applied pressure would oppose the imbibitional pressure, allowing the water but not solutes to escape. This would result in a dilution of the vacuolar sap with a decrease in the freezing point of the expressed sap. On the other hand, if disorganization increased the electrostatic properties of the colloidal components, water would be absorbed and the freezing point of the vacuolar sap increased.

An increase in the freezing point of the expressed sap could also result from the adsorption of vacuolar solutes onto the colloidal components of the cytoplasm and cell wall.

Information on the water relations of the cytoplasm is badly needed. What is required is accurate information on the ratio of water held by diffusible solutes and that held by fixed charges. Also information is needed about the role of metabolism in the maintenance of the fixed charges which are the basis of the imbibitional properties of the cytoplasm. If, for instance, the electrostatic properties are maintained in some way by metabolism, then the activity of water in living and dead cytoplasm can be expected to be different—probably less in the latter.

All the factors briefly mentioned cannot be neglected when considering the nature of the expressed sap. In fact, the chance of the expressed sap resembling the vacuolar sap of living tissue seems remote. Unfortunately, few experiments aimed at assessing vacuolar contamination have been made. It is to be expected that contamination should vary according to the ratio of cytoplasm:vacuole. The data existing are conflicting. With young cells, all cytoplasm, the discrepancy between the plasmolytic and cryoscopic values is small (Currier, 1944), whereas with leaf tissue, having a high cytoplasm:vacuole ratio, the discrepancies are very large (Mason and Phillis, 1939). With the large coenocytic *Nitella* cells, where the expressed sap is most likely to be pure vacuolar sap, the discrepancy is very small (Wildervanck, 1932).

Just how much contamination of the vacuolar sap by vacuolar and wall materials occurs during extraction is, at the present moment, impossible to assess; but that contamination must occur cannot be denied. Mostly the errors we have considered would give an underestimate of the real cryoscopic value for the vacuolar sap.

On the other hand, the errors which have been claimed to exist in the plasmolytic method lead to an overestimate of the plasmolytic value. First, detection of the point of incipient plasmolysis is not easy. In fact it may not be observable immediately the turgor pressure becomes equal to zero, and a slightly higher concentration may be needed to make plasmolysis visible. Also, according to Buhmann (1935) yet higher concentrations, as much as x atmospheres, must be used to overcome the adhesion of the cytoplasm to the cell walls. Levitt, however, concluded that adhesion forces are negligible, since he could detect no difference between the plasmolysis value obtained by plasmolysis and by deplasmolysis.

Another possible source of error is concerned with the volume-correction factor used in comparing the plasmolytic and cryoscopic values. Usually the two values are determined on cells at different degrees of turgor, the cryoscopic on turgid cells and the plasmolytic on cells at incipient plasmolysis. The two values have to be corrected for the difference in the volume of the tissue at the different states of turgor. Most investigators have used a correction factor of *ca.* five per cent. Mainly owing to the difficulty of measuring cell volumes, very few accurate measurements of cell volumes at different degrees of turgor have been made. Recently, Mercer (1950), using a newly developed technique of measuring the osmotic volume of tissues, found differences as high as twenty per cent. between the volumes at full turgor and incipient plasmolysis. Consequently, it is possible that the correction factor used in the plasmolytic-cryoscopic comparison is much too small.

A pointer in this direction is seen in the results of Currier (1944), who showed that the discrepancy between the two values decreased from 2·7 atmospheres for sap extracted from turgid cells to 1·1 atmospheres for sap extracted from cells at incipient plasmolysis.

A puzzling feature of the discrepancy between the two values is the tremendous variation observed between different species and different samples of the same species. No satisfactory explanation of such variability has yet been offered. Depending on the point of view one wishes to take, the variability could reflect variations in the magnitude of errors in the methods or in the magnitude of an active water uptake

process. One final point worth mentioning is that the discrepancy is usually greatest in old, senescent tissues, and smallest in actively growing tissues. Yet it could be argued that an active uptake process should be greatest in young tissue where growth is active.

From what has been said of the possible errors in the two methods, conclusions drawn from the discrepancy between the plasmolytic and cryoscopic values should be accepted with caution. In fact until the plasmolytic method can be compared with cryoscopic measurement using sap which is known to be pure vacuolar sap, the conclusions must be accepted with reservations. Until this is done, the discrepancies between the two methods should not be used as evidence of an active water uptake mechanism, and hence as a basis of criticism of the Osmotic Theory.

1. (*b*) *Anomalous volume:pressure relationships.*

The second piece of evidence which has been used to support the "Active Uptake Hypothesis" concerns the anomalous volume behaviour of plasmolysed cells when transferred from one isosmotic solution, sucrose, to another, KCl. In this type of experiment epidermal cells of the onion bulb scale or similar tissue are plasmolysed first in sucrose solution and, after equilibrium is attained, transferred to an isosmotic solution of a salt, say KCl. The volume of the protoplast is recorded throughout. We have pointed out earlier (relationship 1 (*b*)) that according to the osmotic theory the volume of the vacuole should be the same in all isosmotic non-penetrating solutions. In the transfer experiments being considered several investigators (Bennet-Clark; Mercer) have shown that the volume does not remain constant. The volume of the protoplast undergoes spectacular expansions and contractions which would appear to be inexplicable on the osmotic theory. Bennet-Clark and Bexon (1940) realized that such volume changes might occur if the cell walls were differentially permeable to the solutes used. If sucrose diffused slowly and KCl rapidly through the cell walls, temporary changes would occur in the solution between the protoplast and the cell walls. As a result volume changes would occur. Gradually, as the solutes reached equilibrium, the volume would return to the initial volume. This possibility was rejected following the discovery that isolated protoplasts, no cell wall present, underwent apparently similar volume changes. This result, plus some theoretical reasons concerning the diffusivity of substances in cell wall, led Bennet-Clark and Bexon to conclude that the anomalous behaviour must be due to some process of the protoplast. They assumed the process to be the "active water uptake" process. Moreover, because the phenomenon was associated with solutions of electrolytes and non-electrolytes, they postulated that the active process was analogous to electrosmosis. The anomalous behaviour was explained as due to the electrolyte and non-electrolyte solutions altering the potential difference across the cell membrane, and thereby altering the rate of water movement due to electrosmosis.

Later work has shown that the apparently anomalous behaviour of the protoplasts enclosed in the epidermal cells can be explained on the basis of the differential permeability of the cell wall without involving electrosmosis or an active process. As mentioned, the wall explanation was rejected by Bennet-Clark *et al.*, because isolated protoplasts underwent apparently similar volume changes when transferred from sucrose to salt and salt to sucrose. Actually the behaviour of isolated protoplasts as shown by Mercer (1950) is not analogous to the behaviour of the tissue protoplasts. In Mercer's experiments the behaviour of the isolated protoplasts was shown to be due to the protoplasts undergoing changes in shape, not volume. Shape changes can be interpreted as volume changes since under the microscope the apparent diameter is measured and the volume calculated on the assumption that the protoplasts remain spherical throughout the experiment. The apparently large expansions in volume associated with the transfer from salt to sucrose reflected the fact that the protoplast changed from a sphere in KCl to a flattened disc in sucrose. Moreover, it was shown that the changes in shape were caused by the difference in density between the protoplast and the solutions and by the tendency of the protoplast to be distorted at the sucrose-air interface. When the protoplasts were prevented from contacting the sucrose-air interface the large apparent volume expansions did not occur.

The importance of the cell wall in causing the volume changes of the protoplasts within the cell walls was demonstrated by perforating the cell walls at the ends of the plasmolysed protoplast. During transfer the volume changes of the protoplast in the treated cells were almost negligible. These results suggest that the volume changes induced in onion epidermal protoplasts by rapid transfer from one isosmotic solution to another can be explained in terms of the osmotic theory. The fact that the same tissue was used by Bennet-Clark and Bexon strongly suggests that their results may have a similar explanation.

At this point Levitt's (1936) observations on the volume:pressure relationships of the mature vacuolated protoplast of the parenchyma cells of the onion bulb scale became relevant. Levitt found that the volume of the protoplasts was inversely proportional to the osmotic pressure of the external medium. In other words, the mature protoplasts behaved like simple osmometers. Similar results were obtained by Mercer (1950) and Clark and Mercer (1955), using protoplasts isolated from the epidermal cells of the onion bulb scales. In addition, Mercer (1950) and Clark and Mercer (1955) showed that the volume of the protoplast was independent of temperature. A result which is consistent with the view that the volume of the protoplasts is maintained by the osmotic pressure of the cell sap and the osmotic pressure of the external solution. These protoplasts were isolated from the same tissue-type, epidermis, and the same species of plant as that used by Bennet-Clark and Bexon and Mercer to demonstrate the anomalous volume:pressure changes during salt:sugar transfers.

Similar volume:pressure:temperature relationships were observed by Mercer and Clark and Mercer, using the mature vacuolated protoplasts isolated from the petiole of *Begonia* sp., the epidermis of *Tradescantia* sp., the parenchyma cells of Beetroot and Carrot root tissue, and the parenchyma of the peduncle of Iris flowers. These results, for a number of protoplasts isolated from different species, demonstrate the importance of osmosis in the water relations of at least these protoplasts. In fact, these protoplasts functioned like simple osmometers and obeyed, with considerable accuracy, the Boyle van't Hoff Law.

Thus there seems little argument for accepting as evidence for the "Active Uptake Hypothesis" the so-called anomalous volume changes induced in onion epidermal protoplasts (also observed in other tissue) by rapid salt:sugar transfer. In actual fact the behaviour of these cells really provides a striking confirmation of the Osmotic Theory.

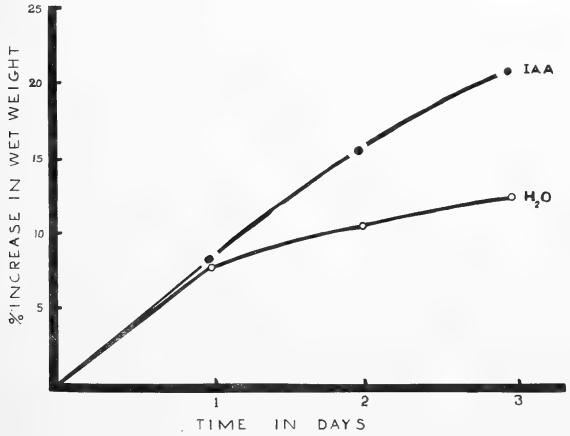
2. (*a* and *b*) *The anomalous water uptake of tissues in which the diffusion pressure deficit is zero.*

Finally, there is the considerable body of evidence supporting the active uptake theory obtained with tissues in which the diffusion pressure deficit is "zero". This evidence is contrary to the relationships 2 (*a*) and (*b*) described earlier. In these experiments pieces of homogeneous tissue such as the parenchyma tissue of tubers and tuberous roots are removed from the organs and stored in aerated water or solutions for several days. From time to time the wet weight is determined and used as a measure of the water content of the protoplasts. By adding various substances to the external solutions the effect of metabolites, auxins, salts and temperature on the water relations of the tissue has also been studied.

If the Osmotic Theory is correct, tissue immersed in a solution should be in equilibrium with the external solution when the diffusion pressure deficit is zero or when it is equal to the osmotic pressure of the external solution. Under these conditions one might expect the volume of the tissue to be independent of time. This expectation does not hold. In general the volume as measured by the wet weight increases with time. This is illustrated by data for the Jerusalem artichoke tuber tissue obtained by McLaren and Mercer (1955) (Text-fig. 1).

All investigators agree that the rapid increase in wet weight observed during the first four to eight hours after immersion in a solution is due to the penetration of water or solution into the intercellular spaces and to the uptake of water by the cells

following the release of tissue tension. After this initial adjustment is complete the diffusion pressure deficit should be zero and no further uptake of water is to be expected. Yet over a period of several days the wet weight increases. Whether this behaviour is inconsistent with the osmotic theory is the point at issue. If either the osmotic pressure or the turgor pressure or both change with time, the diffusion pressure deficit would not remain zero, and the water uptake arising in this way would be consistent with the osmotic theory. Hence before the osmotic theory can be rejected it must be proved beyond doubt that either or both the osmotic pressure and turgor pressure do not alter with time.



Text-fig. 1.—The percentage increase with time in wet weight in grams of Jerusalem Artichoke tissue stored in 10^{-5} molar indol acetic acid I.A.A. and water.

A few typical examples of the experiments and reasoning claimed to disprove such possibilities will be given.

Reindeers (1938) reported the stimulatory effect of auxin on the increase in wet weight and decrease in dry weight of tissues stored in water. Changes in dry weight were used as a measure of the respiratory activity of the tissue. It was argued that, because the increase in wet weight was dependent upon aerobic conditions and because this increase was stimulated by auxin, which also stimulated the loss of dry weight, the increase in wet weight must be controlled by a metabolic process maintained by energy released by respiration and not by osmosis.

Similar conclusions have been reached by other investigators (see Crafts, Currier and Stocking, 1949). Steward, Stout and Preston (1940) criticize Reindeers' assumption that changes in dry weight measure respiration and are of the opinion that her data do not necessarily exclude osmosis. At the same time, however, they conclude from their own data that some kind of active water uptake process occurs in potato tubers kept in aerated KBr and KNO_3 solutions in the absence of auxins. Tissue kept in the salt solutions had a greater fresh weight than those in distilled water. The addition of Ca^{++} ions caused a decrease in the wet weight. The increase in wet weight was correlated with respiration and protein synthesis. These results led them to suggest "that actively metabolizing cells which can grow may absorb water in a manner which has but little relation to any conventional osmotic or suction pressure theory, but may be more directly linked with metabolic processes (respiration and protein synthesis)—processes which are determined by oxygen and affected by the nature of the salts present in the external solution".

The essential point supporting the Active Uptake Hypothesis obtained with the above type of experiment is the fact that the increase in wet weight has the physiological characteristics of a metabolic process, not those of a physical process such as osmosis. It should be remembered, however, that the physiological characteristics may reflect metabolic processes concerned with the maintenance of the osmotic properties of the tissue.

More direct efforts to determine the contribution of osmotic pressure changes in the vacuolar sap have been made by following the cryoscopic value of the sap as the wet weight increases. In general the results indicate that the cryoscopic value tends to remain constant or to fall slightly. The data obtained by van Overbeek (1944) will serve to illustrate the point. Auxin-treated tissues had a lower osmotic pressure than the controls in water. As the difference between the osmotic pressure of the treated and control tissues could be accounted for by the extra water in the auxin-treated tissue, van Overbeek concluded that there was no change in the total solute content of the tissue. Hence it seemed improbable that changes in the osmotic pressure of the cell sap could have been responsible for the increase in the wet weight of the tissues. It was concluded that either changes in turgor or a non-osmotic water uptake process was concerned.

Another approach to the question of the roles of turgor and osmotic pressure changes, has been the study of the water relations of tissues in hypotonic solutions. Many investigators have shown that the wet weight of tissue in hypotonic solutions may increase even though plasmolysis has occurred. This fact is shown by results obtained by Commoner, Fogel and Muller (1943), who found that auxin could prevent the loss of weight by tissue immersed in 0·2M. (hypotonic) sucrose solutions. Addition of potassium chloride and fumarate increased the wet weight further. The authors concluded that the water uptake was associated with salt accumulation, and that auxin and the organic acids stimulated water uptake indirectly via the salt accumulation process. Such an explanation overlooked the fact that wet weight increases occur in distilled water and auxin solutions—no salt present. Thus, although salt accumulation may be a contributory process under some circumstances, it cannot be the general explanation.

The importance of the experiments using hypotonic solutions lies in the two conclusions which have been drawn from the results. First, since the cells were plasmolysed turgor changes can be rejected as a cause of the increases in wet weight. Secondly, the increase in wet weight must have occurred against an osmotic pressure gradient. These conclusions would appear to eliminate the possibility of osmotic factors playing a role in the increase in wet weight of tissues in hypotonic solutions. Consequently the increase in wet weight has been attributed to an active uptake process.

More recently, Bonner, Bandurski and Millerd (1953) examined the effect of auxin on the wet weight of tuber tissue of Jerusalem artichoke in both hypertonic and hypotonic solutions.

They confirmed the earlier observations that wet weight increases can occur in hypertonic solutions, that is, where turgor effects do not operate and where the increase in wet weight must have occurred apparently against an osmotic gradient. In addition, they showed that auxin stimulated respiration. Clearly, since the tissue was plasmolysed the auxin effect could not be via changes in the cell wall. Bonner *et al.* concluded that the auxin acts via the active uptake mechanism, which is linked to respiration.

During the last ten years or so it has been shown conclusively that energy-requiring cell processes are linked to respiration via the phosphate bond transfer mechanism. The substance dinitrophenol is known to uncouple the link between respiration and the energy transfer mechanism. Hence by treating tissue with dinitrophenol processes requiring energy are inhibited. As an example of this, one can mention Robertson's (1951) work showing the inbibition of salt uptake by 10^{-3}M. dinitrophenol. Bonner *et al.* argued that if water uptake is an active process, then treatment of tissue with dinitrophenol should inhibit the process. Experiments were in agreement with the

hypothesis. Treatment of tissue with dinitrophenol abolished the increase in the wet weight in both auxin-treated and control tissue. They concluded, therefore, that the increase in wet weight of the tissue must have been caused by an active uptake process.

Further support for this idea of an active uptake process playing a role in water relations has come from experiments using coleoptile segments in place of discs of tissue. It is sufficient to mention one or two experiments. Kelly (1947) showed that auxin increased both respiration and the wet weight of coleoptile segments under aerobic but not anaerobic conditions. This behaviour is identical with that observed for storage tissue. In addition, it was argued that if an active uptake process maintained by respiration exists, then inhibition of respiration should inhibit water uptake. It was found that the respiratory inhibitors azide and iodo-acetate prevented the increase in wet weight. Hence it seemed reasonable to assume that an active uptake process is concerned with the increase in wet weight of coleoptile segments.

Similar conclusions have been reached from experiments on the nature of root presssure (Rosene, 1944; van Overbeek, 1942). Briefly it has been shown that the rate of exudation from decapitated roots is depressed by respiratory inhibitors such as KCN, is temperature dependent, and depressed by anaerobic conditions. Also van Overbeek made the interesting observation that the osmotic pressure of mannitol solutions required to stop exudation from tomato roots was always from fifty to seventy per cent. greater than the osmotic pressure of the exudate. The difference was interpreted as due to an active uptake process. On treatment of the roots with 10^{-4}M. KCN the discrepancy was reversibly inhibited. Such behaviour strongly indicates that a metabolic process is concerned. It is but a short step to assume that the metabolic process is an active water uptake process dependent upon respiration.

At this point it is useful to summarize the evidence supporting the Active Uptake Hypothesis. Certain experimental results suggest that the increase in the wet weight of tissues stored in water or certain solutions cannot be attributed either to changes in turgor or changes in the osmotic pressure of the vacuolar contents. On the other hand, the increase in wet weight has the following physiological characteristics: (1) a high temperature coefficient, (2) dependent upon aerobic conditions, i.e. O_2, (3) stimulated by auxin, which also increases respiration, (4) is inhibited by respiratory inhibitors such as azide, iodacetate, potassium cyanide, and is (5) inhibited by dinitrophenol, which uncouples the energy transfer mechanism. These observations would appear to provide strong evidence for a metabolic process. Consequently many plant physiologists accept the view that an active non-osmotic component plays a role in the water relations of such widely different processes as root pressure, coleoptile segments and parenchyma tissue slices.

In any controversial issue there is always the opposite view as well as conflicting experimental results. Levitt (1947), for example, using potato tissue and the same technique as used in the other experiments with tissue slices, found that the respiratory inhibitor (KCN) did not inhibit the auxin-induced increase in wet weight of the slices. Also, contrary to Stile's result, he found that the wet weight was not dependent on the temperature. Reduction of the temperature from *c.* 25°C. to 1°C. did not cause a loss of water from tissue previously stored at 25°C. Conflicting results are known also for root pressure. Skoog, Broyer and Grossenbach (1938) found no correlation between respiration and the rate of exudation from decapitated sunflower roots. Burström (1953) has criticized the results obtained by Bonner, Bandurski and Millerd, claiming that the permeation of mannitol increased the osmotic pressure of the vacuolar sap and as a result water was absorbed along an osmotic gradient. Taken alone, such conflicting results cannot be regarded as sufficiently strong evidence for rejecting the active uptake hypothesis as applied to wet weight data. Time does not permit a complete analysis of all the data obtained in wet weight experiments. Consequently only a critical assessment of the more significant experiments will be attempted.

Burström, in repeating the experiments of Bonner *et al.*, measured not only the wet weights but also the cryoscopic values of the tissues. The final cryoscopic values were found to have increased almost proportionally with, and to be greater than, the

osmotic value of the external solutions. Since the final values were greater than the osmotic values of the solutions, Burström concluded that the increase in wet weight must have occurred in the direction of an osmotic gradient, not against a gradient as claimed by Bonner *et al.*, and others. Moreover, he argued that the extra osmotic pressure of the vacuolar sap must have been due to the penetration of mannitol into the vacuoles. The possibility that it was due to solution held in the intercellular spaces was rejected since the final cryoscopic values were always greater than the initial value plus the osmotic value of the particular solution. Since Bonner *et al.* used the same type of tissue and solutions Burström concluded that their results must have been caused also by the penetration of mannitol, and therefore have little value as evidence for the active uptake hypothesis.

Burström's conclusions are extremely important, for, if correct, most of the evidence supporting the "Active Uptake Theory" based on the water relations of tissues in hypotonic solutions must be rejected. In view of this it becomes essential to consider his results in more detail.

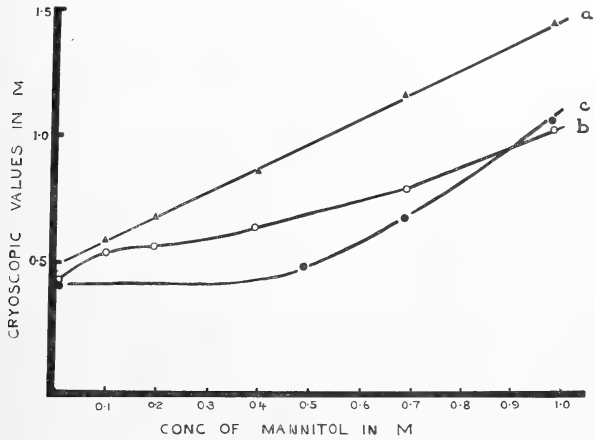
The point made by Burström from his results is that the cells became permeable to mannitol, which increased the osmotic pressure of the cell sap, leading to an osmotic absorption of water. Before examining this conclusion it is necessary to consider the processes which are known to occur when a cell is placed in a solution of a permeable substance. Initially there is a loss or gain of water depending upon the concentration of the solution and the initial diffusion pressure deficit of the cell. Plasmolysis may or may not occur. Then, as penetration commences, the osmotic pressure of the cell sap gradually increases, leading to the absorption of water. These processes continue until equilibrium between the cell and the external solution is attained. Equilibrium occurs when the internal and external concentrations of the permeable substance are equal, and when the diffusion pressure deficit is zero. The diffusion pressure deficit becomes zero at full turgor.

An examination of Burström's results, the wet weight time curves, shows that equilibrium had almost been attained after one hour. Consequently it seems reasonable to assume that equilibrium must have been established after fifty-four hours. Hence if permeation occurred, as claimed, then the concentration of mannitol within the cells should have been equal to the concentration of mannitol in each solution. In addition, the cells should have been fully turgid in all solutions. Under these circumstances one would have expected the wet weights of the fully turgid cells to have been the same in all solutions. Actually the results show that the wet weights decreased as the concentration of the external solutions increased. This observation really proves that permeation could not have occurred.

However, Burström argued that permeation must have occurred because the cryoscopic value of the tissue increased more or less proportionally with the osmotic pressure of the external solutions. We have seen that if permeation occurs, then, at equilibrium, the internal and external concentrations of the penetrating substance must be equal. Since in Burström's experiments equilibrium had been attained the cryoscopic values of the cell saps should have been equal to the initial cryoscopic value, 0·495M., corresponding to the cryoscopic value of the cell sap plus the cryoscopic value for the particular solution. For example, the cryoscopic value of the tissue immersed in the 1·0M. solution should be 1·495M. and that of the tissue in 0·5M., 0·995M. Curve *a* (Text-fig. 2) shows the cryoscopic values expected for all solutions. Actually the values observed were much less (curve *b*, Text-fig. 2). The difference between the two curves argues against permeation.

It is interesting to estimate the cryoscopic values which one might expect assuming no penetration. Under these conditions, for tissues at equilibrium, the diffusion pressure deficit of the tissue must be equal to the osmotic pressure of the external solution in each solution. Since the initial cryoscopic value of the tissue was at 0·495M., one can assume that plasmolysis would have occurred in the 0·5M. solutions. In the more concentrated solutions 0·7M. and 1·0M. exosmosis of water would have increased the diffusion pressure deficit to 0·7M. and 1·0M. respectively. In the more dilute solution

a gain or loss of water, depending on the value of the initial diffusion pressure deficit of the tissue, is to be expected. From the data the initial diffusion pressure deficit would appear to have been at *c.* 0·2M., since no gain or loss of weight was recorded in this solution. Unfortunately, not knowing the magnitude of the actual changes in volume of the tissue, gain or loss, occurring in the solutions 0·495M. to water, it is not possible to predict accurately the cryoscopic value expected for the tissues in these solutions. All that can be done is to indicate that the value in water would be a few per cent. less than 0·495M. through dilution, and approaching 0·495M. in the



Text-fig. 2.—The cryoscopic value of the tissue plotted against the concentration of mannitol in M. Curve *a*: Values expected if complete permeation of mannitol. Curve *b*: Values observed. Curve *c*: Values if no permeation of mannitol.

more concentrated solutions. The difference in wet weight between the tissue in water and the 0·2M. solution was only *c.* two–three per cent. The cryoscopic values expected if no permeation occurred are shown by curve *c* (Text-fig. 2). Burström expressed surprise that the cryoscopic values of the expressed sap increased proportionally with the external concentration of the solutions, and concluded permeation must have occurred. As shown by curve *c* (Text-fig. 2), a similar relationship also arises without permeation. These values, however, are less than those obtained by Burström.

The theoretical limits for the cryoscopic values expected for the expressed saps for either complete permeation or for no permeation at all are both different from the observed results (curves *a*, *b*, *c*, Text-fig. 2). The observed result falls approximately midway between the two. It must be remembered that we are dealing with tissue at equilibrium, therefore one of the above results should have been obtained. In view of the fact that the wet weights of the tissues decreased, that is, the tissues were not at full turgor, curve *c* for no permeation is taken to be the correct theoretical limit for the cryoscopic values. The explanation of the differences between the curves is not immediately apparent. It is not improbable that it lies in the assumption that sap expressed under pressure is pure vacuolar sap.

A note of warning concerning the use of molar and molal solutions can be inserted at this stage. It is by no means clear, from the results in the majority of papers published on water relations of tissues in hypotonic solutions, which type of solutions were used. For example, apparently the symbol M. used by Bonner *et al.* referred to molar solutions, since the same symbol was used for the auxin solutions as well as the hypertonic solutions. On the other hand Burström, certainly as far as the cryoscopic

values of the expressed saps are concerned, used the symbol M. for molal solutions. One cannot decide from his results whether the M. used for the mannitol solutions refers to molar or molal. To avoid confusion and error, investigators should indicate the meaning of the symbol M. used when expressing concentrations. For example, a molar solution of mannitol is equivalent to a *ca.* 1·13 molal solution. Comparison of results obtained using the different types of solutions could lead to apparent discrepancies.

Although no explanation can be offered for the larger than expected cryoscopic values obtained by Burström, the main fact remains that the results do not support the conclusions. To the contrary, they indicate that permeation could not have occurred. Hence one must reject Burström's evidence as a basis of criticism of the "Active Uptake Theory".

Yet the observation that the wet weight does not decrease to the extent expected on osmotic grounds remains. In Bonner's experiments incipient plasmolysis was at 0·12M., hence one might expect the wet weight to have decreased by half in a 0·24M. solution. Similarly in Burström's experiments the wet weight should have decreased by half between 0·5M. and 1·0M. This anomaly is the essential evidence on which the "Active Uptake Theory" rests.

In all the research on the water relations of tissue slices in hypotonic solutions which has so far been published no measurements of cell volume have been attempted. Invariably it has been assumed that wet weight can be used as a measure of the volume and water content of the protoplasts of the tissue. The validity of this assumption has never been questioned. The error arising from this oversight is well shown by some of the results obtained by persons working in the Department of Botany at the University of Sydney.

McLaren and Mercer (1955), using a technique based on Archimedes' principle—a body immersed in a solution displaces its own volume of solution—have compared the apparent osmotic volume of tissues immersed in solutions of different concentrations with the wet weights of the same tissues.

The Apparent Osmotic Volume is essentially a measure of the total volume of the protoplasts in a tissue. The technique was developed by Professor G. E. Briggs, of the Botany School, University of Cambridge, England, and is reported fully in a dissertation for the Ph.D. degree submitted to that University by the present author (1950).

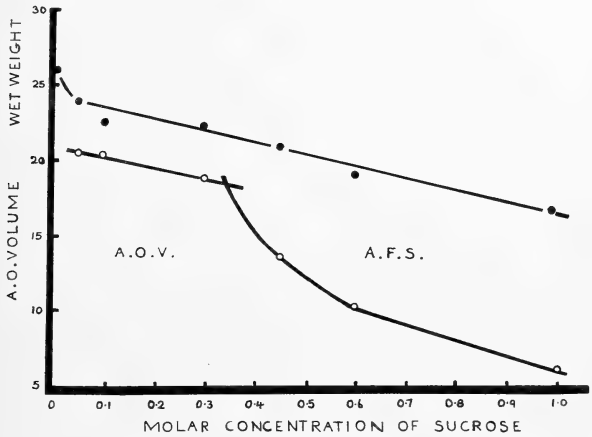
From Text-figure 3 it can be seen that, except for dilute solutions, wet weight is not a measure of volume. Essentially similar results have been obtained for potato, carrot, beetroot and Jerusalem artichoke tissue. The reason for the lack of correlation is obvious. After plasmolysis the Apparent Free Space of the tissue increases as the protoplasts shrink. Volume previously occupied by the protoplasts becomes filled with the external solution. The wet weight, therefore, includes not only the weight of the protoplasts, but also the weight of the solution in the Apparent Free Space. It is easy to see how wet weight measurements could give the impression that water uptake can occur from hypotonic solutions. We feel that many of the results so far published for the water relations of tissues in hypotonic solutions can be explained in this way. One must conclude that most of the data published by van Overbeek, Bonner *et al.*, Burström, and others have little meaning in so far as the problem of water relations is concerned.

Much of the variability in the magnitude of the so-called uptake obtained by different investigators may also be readily explained as due to variations in the rigidity of the cell walls and to the pressure used for drying the tissues. It is to be expected that tissues with rigid walls, which would contract less following plasmolysis and which would resist compression during drying, would show an apparently large uptake. The importance of the pressure used when drying tissues for wet weight measurements has been clearly demonstrated by Ashby and Wolf (1947).

Another extremely important finding arising from the Apparent Osmotic Volume experiments is the form of the volume:pressure relationships. One of the relationships expected from the Osmotic Theory is that the volume of a plasmolysed cell should vary inversely as the reciprocal of the osmotic pressure of the external solutions. The

Apparent Osmotic Volume, after plasmolysis, does in fact obey such a relationship. Thus when volumes, not wet weights, are considered, the water relations of tissues in hypotonic solutions support rather than disprove the Osmotic Theory.

Although the lack of correlation between wet weight and volume invalidates most of the conclusions previously reached from tissue slices in hypotonic solutions, it is most unlikely to be the explanation of the increase in wet weight observed for tissues stored in water, auxin solutions or very dilute solutions. In these solutions the tissues would be turgid, and the wet weight, apart from the small amount of solutions in the



Text-fig. 3.—The relationship between the wet weight in grams and concentration of the external solution ·—· and the relationship between the apparent osmotic volume in c.c. and concentration of the external solution o—o.

intercellular spaces which presumably would not alter with time, should give a reasonably accurate measure of cell volumes. The explanation of the increase in wet weight in water, and the stimulatory effect of auxin must be sought elsewhere. It must be emphasized, however, that before rejecting the Osmotic Theory, rigid proof that changes in either or both the osmotic pressure of the cell sap and the turgor pressure do not occur. The fact that with the tissue slice technique most experiments last for several days at least, the possibility of changes in these quantities must not be overlooked.

These possibilities have long been realized, but the experimental evidence of their significance is conflicting. In general, the results show that the osmotic value of the sap tends to remain more or less constant, or to decrease slightly as the wet weight increases. Despite the conflicting nature of the results, and remembering that osmotic values are frequently determined by the cryoscopic technique, there is a strong indication that the osmotic pressure tends to remain constant. This is an extremely important possibility, for, if proven, it means that the total number of osmotically active particles must increase along with water uptake. Or in other words, water uptake follows the synthesis of osmotic material.

With turgid cells the volume and, therefore, the area of the cell walls increase during water uptake. This implies a stretching of the walls. Consequently, changes in wall elasticity cannot be overlooked as playing a role in the uptake of water. The stimulatory effect of auxin may arise through the action of auxin on wall structure. There is some evidence to show that auxin is in some way concerned with the physical property of the cell wall. This possibility of turgor changes has been recognized, but the difficulties of measuring turgor pressures directly have hindered experimental work.

One interesting result obtained with the Apparent Osmotic Volume technique by McLaren and Mercer is that the Apparent Osmotic Volume of tissues after four days in both water and in auxin solutions varied inversely as the reciprocal of the osmotic pressure of the external solutions. This result, which refers to the final volume, does not necessarily indicate the changes which must have taken place as the volume increased with time. Unfortunately, comparative data for auxin-treated and control tissues have not been obtained over the same intervals. In experiments carried out at different times the Apparent Osmotic Volume for both auxin-treated and control tissue obeyed the Laws of Osmosis. These results, which are as yet tentative, strongly indicate that the importance of osmotic processes in controlling the uptake by tissues in water and auxin cannot be dismissed too lightly.

As we have seen, no satisfactory explanation has yet been proposed to explain the water relations of tissue slices in water and auxin solutions. Despite this failure, there seems no good reason for rejecting the Osmotic Theory, particularly in view of the tentative Apparent Osmotic Volume data. Further speculation would be fruitless. Experiment must supply the answer.

Turning next to the so-called physiological properties of the active uptake process in tissue slices in water and solutions, namely oxygen dependence, inhibition by respiratory inhibitors, high temperature coefficient and so on. It does not follow necessarily, because the wet weight of tissues is dependent upon the oxygen tension or is inhibited by respiratory inhibitors, that the increase in water absorption must be caused by an active uptake of water. Such a conclusion is far from warranted, especially since alternative explanations can readily be proposed. Correlations do not necessarily imply causation. There is room for speculation, and in an address of this kind one is allowed to speculate.

Little is known regarding the nature of the processes controlling the osmotic pressure of the cell sap in a tissue which is not deriving osmotic material from an external source. One important factor would be the balance between synthesis and breakdown. This would not be a single process, but a reflection of the overall metabolism of the tissue. In recent years tracer studies with carbon and nitrogen have demonstrated the extreme lability and interdependence of metabolic processes. In the steady state the metabolic processes proceed at certain uniform rates, continuing collectively, so to speak, to give the metabolism of the so-called resting cell. Synthesis and breakdown are balanced such that a particular level of solutes is present in the vacuolar sap. One might expect that any experimental treatment which influences almost any aspect of metabolism will eventually affect the concentration of solutes in the sap.

A few examples will be considered. Respiration is the key process in cell metabolism. Alteration in the respiration rate is likely to have a profound effect on many properties of the cell. One property which is dependent upon respiration is the organization and permeability characteristics of the cell membranes. Suppression of respiration either by inhibitors or a lowering of the oxygen tension is likely to increase the permeability of the cell membrane leading to a leakage of solutes from the vacuole. In this way the osmotic pressure would fall, resulting in the exosmosis of water. A loss of volume (or wet weight) arising in this way could be interpreted as due to the inhibition of an active water uptake process. It would be interesting to determine leakage rates of tissues treated for several days with cyanide or dinitrophenol.

The balance between synthesis and degradation, since enzymatic processes are involved, could well be temperature dependent. The high temperature coefficients sometimes observed for the water uptake by tissue slices in water could reflect a shift in the synthesis:degradation balance. At the best, a temperature coefficient is but a crude index of the metabolic activity of cells. To assume, solely on the grounds of temperature coefficients, the existence of an active water uptake process is unwarranted. A particular example of the possible importance in the shift from synthesis to breakdown may be the observation that the uptake of water by potato tissue slices has a high temperature coefficient, whereas the coefficient for carrot is low (Stiles, 1917). In potato which

has a high starch content, a shift in the starch:sugar balance may occur with high temperatures, leading to an increase in the osmotic pressure of the cell sap and to the increased uptake of water. Carrot is starch free, and has a low coefficient. In this example the high temperature coefficient for water uptake is apparent, not real. In a similar way, temperature may influence other cell processes via enzymatic processes and thereby water uptake.

The so-called physiological properties of water uptake do not provide unique evidence for an active uptake process. At the best, they probably reflect the general metabolic activity of the tissues. For this reason, and also since alternative metabolic explanations can be suggested, the conclusions based on the physiological properties should not be accepted too seriously.

There remains the difficulty of explaining the similar physiological properties of root pressure and exudation. Here again, factors such as temperature may influence the general metabolic activity rather than a unique water uptake process. The mechanism of root pressure is rather more complicated than the water relations of parenchyma cells. The essential feature of the process is the maintenance of an osmotic gradient between the xylem cells and the surrounding cells. The maintenance of the gradient through the secretion of solutes may well be the "active process" in root pressure. Water movement simply follows passively the solute movement. If such be the case, then the meaning of the physiological properties of root pressure and exudation becomes apparent.

Inhibition of the secretion of solute through a lowering of the temperature or through cyanide or azide would indirectly inhibit water movement. If water movement is the quantity measured, then it must have the physiological characteristics of a secretory process. We feel that this is likely to be the explanation of the active water uptake process in roots. Time does not permit a full discussion of the voluminous results on the problem, so the matter must be left here.

Also because of time, the water relations of oat coleoptiles, despite their obvious bearing on the active water uptake problem, cannot be discussed in any detail. However, a few general comments will be made—the first being to emphasize that the water relations of the coleoptile are much more closely associated with the problem of growth, whereas those of the tissue slices already discussed are essentially those of mature cells in which growth is absent or very limited. It is to be expected that the water relations of coleoptiles will be more complicated and more difficult to unravel. But as with the tissue slices, the explanation should be sought first in terms of changes in the osmotic quantities of the cells. Since the volumes of the cells increase to such an extent during the uptake of water, changes in the cell wall are likely to play a correspondingly greater part. Also since cell volumes increase greatly, the synthesis of cytoplasm and other cell components must influence the water uptake mechanism. The water relations problem in these tissues is probably an aspect of growth concerned with the synthesis of new cell wall material, cytoplasm, and osmotically active solutes.

In all probability, the physiological attributes of the water uptake in coleoptiles, as with the other tissues considered, reflect aspects of cell metabolism, but because of their immaturity, inhibitors, oxygen tension, temperature, and so on, are likely to have more spectacular effects. Inhibition or stimulation of water uptake by some external factor does not necessarily prove the existence of an active uptake process. The stimulatory effects of auxin must await a fuller understanding of the role of hormones in growth. So long as the possibility of auxin affecting the osmotic concentration of the cell sap via other metabolic processes or of auxin controlling wall growth and structure remains unproven, it would seem unwise to postulate that the auxin effect is via an active water uptake process.

In this address we have not been able to discuss all the anomalous results relating to the water relations of cells and tissues. Only some of the more important pieces of evidence on which the Active Uptake Theory has been based have been considered. We have shown that much of this evidence is open to serious criticism and should be rejected. In fact, when allowance is made for errors of technique and interpretation,

many of the so-called anomalous results have been shown to support, not to disprove, the Osmotic Theory. For the reasons which have been stressed already there seems little ground for postulating, from the evidence available, the existence of an active water uptake process in plant cells. Anomalies remain, and time alone will decide whether these reflect an active uptake process.

The Osmotic Theory: A Restatement.

The number of examples showing that mature cells obey the laws of osmosis is so large that it is difficult not to accept the Osmotic Theory as an important and proven generalization concerning cell function. Admittedly the theory does not explain all known observations relating to the water relations of cells. We have seen in this address that many of the discrepancies between the behaviour expected on osmotic grounds and that observed are not contrary to the Osmotic Theory. Consequently, we seem justified in believing that other anomalous behaviour will also be explained within the framework of the Osmotic Theory.

One type of anomalous behaviour which will have a significant bearing on the future of the water relations problem is the small differences in volume observed between cells plasmolysed in isosmotic solutions of electrolytes and non-electrolytes. For example, the overall volume of the protoplast is greater in potassium nitrate solution than in sucrose or calcium chloride solutions. These differences appear to be associated with the cytoplasmic phase, and raise the problem of the water relations of the cytoplasm as opposed to that of the vacuole.

At the beginning of this address we mentioned that the Osmotic Theory was formulated to explain the water relations of the mature, not the meristematic, cell. Clearly some modification is required to cover all cells. Between the meristematic and the adult cell a whole range of cells occur in which a changing ratio of cytoplasm to vacuole is the most striking morphological characteristic. The overall water relations of the protoplast must be considered as the resultant of the water relations of vacuole and cytoplasm. The questions which must be answered in the future are "What are the similarities and differences between the water relations of these two systems?" and "Do active water uptake processes function in the cytoplasm?"

Ideally the Osmotic Theory requires the existence of a semipermeable membrane and a solution phase. This fact has been recognized from the beginning, and plenty of effort has gone into identifying these units with structures in the protoplast. With the mature cell no difficulties were experienced in identifying the solution phase with the vacuolar sap, but the position of the semipermeable membrane has always been a matter of controversy. Semipermeable properties have been ascribed to the tonoplast, to the external layers of the cytoplasm next to the cell wall, and to the cytoplasm as a whole. That the tonoplast has semipermeable properties was first clearly indicated by Höfler, who found that the vacuole-tonoplast system can remain intact and undergo volume changes without the enclosing layers of cytoplasm. More recently conclusive proof of the semipermeable nature of the tonoplast has been obtained by Mercer (1950) and Clark and Mercer (1955), who studied the water relations of both isolated vacuole-tonoplasts and isolated intact protoplasts. Both structures obeyed the Boyle van't Hoff Law almost exactly. Since the tonoplast-vacuole system functioned alone, it would seem certain that this system represented the osmometer of the intact protoplast. Similar conclusions relating to the position of the semipermeable barrier have been reached indirectly by other techniques. If the tonoplast-vacuole system is the osmometer of the protoplast, "what of the cytoplasm?".

Most of the evidence relating to the structure of cytoplasm supports the view that cytoplasm is a complicated sol:gel system. Furthermore, optical, differential centrifugation and other data show that the cytoplasm is differentiated into a more or less sol-like fraction containing the particulate structures such as the mitochondria and plastids. More recently electron microscope studies have confirmed this general structure. An electron micrograph of mature plasmolysed cells of beetroot, and turgid cells of *Nitella* obtained by Hodge, McLean and Mercer (1955) is shown in Plate A,

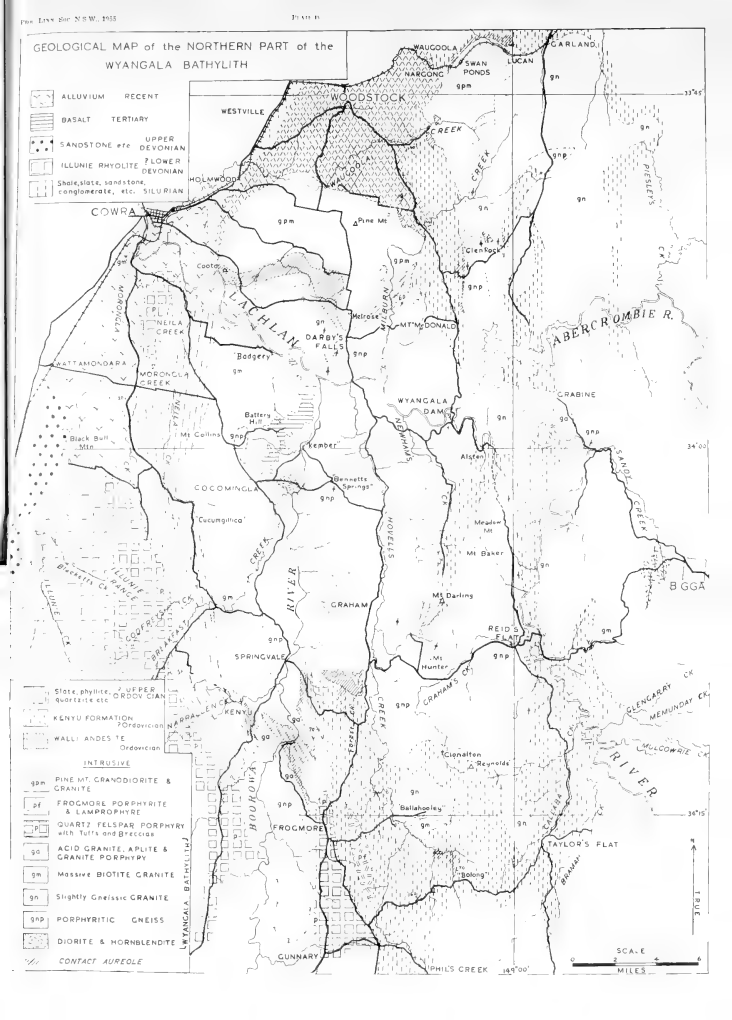

GEOLOGICAL MAP of the NORTHERN PART of the WYANGALA BATHYLITH
ALLUVIUM RECENT
BASALT TERTIARY
SANDSTONE etc UPPER DEVONIAN
ILLUNIE RHYOLITE ? LOWER DEVONIAN
Shale, slate, sandstone, conglomerate, etc. SILURIAN
Slate, phyllite, ? UPPER quartzite etc ORDOVICIAN
KENYU FORMATION ? Ordovician
WALLI ANDESITE Ordovician
INTRUSIVE
gpm PINE MT. GRANODIORITE & GRANITE
pf FROGMORE PORPHYRITE & LAMPROPHYRE
rp QUARTZ FELSPAR PORPHYRY with Tuffs and Breccias
gg ACID GRANITE, APLITE & GRANITE PORPHYRY
gm Massive BIOTITE GRANITE
gn Slightly Gneissic GRANITE
gnp PORPHYRITIC GNEISS
DIORITE & HORNBLENDITE
CONTACT AUREOLE
WYANGALA BATHYLITH
WOODSTOCK
WESTVILLE
HOLMWOOD
COWRA
LACHLAN R.
MORONGLA CREEK
NATTAMONDARA
Coota
Badgery
Melrose
MT. MCDONALD
DARBY'S FALLS
Pine Mt
Glenfoss
ABERCROMBIE R.
WAUGOOLA
NARGONG
SWAN PONDS
LUCAN
CARLAND
WYANGALA DAM
CRABINE
Alstein
Kenber
Batterys Hill
Mt Collins
Black Bull Mtn
COCOMINGLA
Bennetts Springs
Cucumgilica
Meadow Mt
Mt Baker
Mt Darling
GRAHAM
REIDS FLAT
Mt Hunter
SPRINGVALE
ILLUNIE R.
Brassetts Ck
COOPERS CK
GRAHAMS CK
GLENCARRY CK
MEMUNDAH CK
MULGOWRIE R.
BIGGA
Cionalten
Reynolds
Ballahooley
FROGMORE
TAYLORS FLAT
Bolong
BRANDY CK
GUNNARY
PHILS CREEK
SCALE
MILES
149°00'
34°00'
33°45'
36°15'

fig. 1. The cytoplasm can be seen to consist of a deeply staining background material containing "empty areas" and mitochondria and plastids. Frequently the background material is further differentiated into linear aggregates as well as more or less homogeneous regions. There are no means available for telling just how far the structure of living cytoplasm corresponds with the fixed material as seen with the electron microscope. Since the structure is consistent with that postulated from other evidence, it seems reasonable to assume that the gross structure of the cytoplasm is similar to that seen with the electron microscope. Consequently it is assumed that the "empty areas" correspond to spaces previously occupied by solution and the densely staining material to the colloidal micelles of the solid phase of the living cytoplasm.

The electron microscope work shows beyond doubt the presence of two membranes in the adult plant cell (Plate A, fig. 2). This important observation supplies direct proof of the position and number of the main cell membranes, and clarifies an issue of fifty years' standing.

Finally, the electron microscope studies show that the particulate components, the mitochondria and plastids, consist of numerous, more or less well organized, densely staining lamellae embedded in a homogeneous, faintly granular material, and enclosed by a definite membrane.

Since cytoplasm has many of the properties of a gel system, it is useful at this point to look at the nature of the water relations of a fully imbibed protein gel. The water in a gel may be held by various electrostatic forces, either directly via hydrogen bonds and van der Waal forces, or indirectly through the osmotic influence of dissociable ions associated with the gel micelles. The force with which the water is held in the gel can be measured by the application of an external hydrostatic pressure, as is the case with a simple osmometer. Thus the imbibitional pressure so measured is analogous to an osmotic pressure. The distinction lies in the nature of the solutes responsible for the two types of pressure. In the simple osmometer the solutes are freely diffusible, whereas in the colloidal osmotic system the solute particles are non-diffusible, being held by the electrostatic charges of the colloidal micelles. The swelling of a colloid may be limited or non-limited, depending on the cohesive forces binding the colloidal micelles. Thus the water relations of a gel are determined by osmotic forces and the cohesive forces of the gel framework. The volume changes of a gel which occur during swelling will tend to obey the Laws of Osmosis, but deviations will occur, depending on pH, which influences the degree of dissociation of the groups providing the electrostatic bonds, and on temperature and the nature of the solutes present which influence the cohesive forces. Thus a gel is a particular kind of osmotic system in which the whole of the gel framework can be pictured as a semipermeable membrane, and the solution phase as being continuous throughout the membrane. This concept provides a useful basis for considering the water relations of the cytoplasm.

The well-known observations that the swelling of cytoplasm is a function of pH, the ionic composition of the external medium, and of temperature, show how closely the water relations of cytoplasm resemble those of a non-living gel. Despite these similarities, the possibilities of differences between the behaviour of the living and non-living systems should not be overlooked. In the absence of exact information about the water relations of cytoplasm, one cannot exclude the possibility of an active uptake process contributing to the water balance of cytoplasm. Another possibility, which we consider the more likely, is that the electrostatic and cohesive properties of cytoplasm are under the control of metabolism. Metabolism might affect the state of the cytoplasm via changes in the pH of the cytoplasmic solution, the concentration of solutes, the number of hydrogen bonds. If metabolism plays such a role, then the swelling of cytoplasm might differ considerably from the expected by analogy with a non-living gel. In this way the water relations might be found to have the physiological characteristics of a metabolic process, even though osmotic forces directly control the water balance.

The discussion of the water relations of cytoplasm would be incomplete if reference to the water relations of the particulate structures like the chloroplasts and mitochondria

were omitted. Evidence which is available indicates that these structures are highly organized lipoprotein systems of relatively low water content. Unpublished work (Farrant, Robertson and Wilkins, 1955) showed that the qualitative swelling of mitochondria varied with the osmotic pressure and ionic composition of the external solutions. In a recent paper (Mercer *et al.*, 1955), the swelling of chloroplasts isolated from *Nitella* was shown to obey the osmotic laws over a limited range of swelling, that is, they behaved like gels showing limited swelling because of their structure. In these chloroplasts swelling resulted from the volume changes of the interlamellar protinaceous material between the lamellae (Pl. A, fig. 2). The water balance was determined by the osmotic properties of the interlamellar material and the cohesive properties of the chloroplast. As with bulk cytoplasm, the imbibitional properties of both chloroplasts and mitochondria might be influenced by their metabolic activity. Be this as it may, the important point is that osmotic forces apparently control the water relations of the chloroplast, and possibly the mitochondria.

The evidence which we have discussed suggests that osmotic and cohesive forces determine the water relations of cytoplasm. At the present there does not appear to be any sound reason for assuming that non-osmotic water uptake processes play a contributory role. Thus I accept the point of view that the water relations of both the vacuole and cytoplasm can be interpreted on the basis of the Osmotic Theory.

In conclusion, the following picture of the protoplast is suggested as a working basis for interpreting cell water relations. The protoplast should be regarded as a two-phase system: a tonoplast-vacuole phase consisting of a solution phase enclosed by a semipermeable membrane, which behaves almost as a perfect osmometer; and a cytoplasmic phase, which behaves as a colloidal osmotic system, consisting of a micellar framework interspersed with a solution phase bounded externally by the relatively permeable cell membrane and internally by the tonoplast. Within the cytoplasm are the particulate structures which have the same type of osmo-regulatory mechanism as the bulk cytoplasm, but which, because of their highly ordered structure, show a more limited degree of swelling. Such a picture is not complete without a full appreciation of the osmo-regularity function of metabolism. Metabolism is suggested as the vehicle via which the osmotic pressure of the vacuolar sap and the imbibitional and cohesive forces of the cytoplasm are maintained.

This concept of the protoplast is applicable to all cells irrespective of age. The actual water relations of any particular tissue will depend on the extent to which the colloidal osmotic system contributes to the total water relations, and on the extent of metabolic control under the particular conditions. For this reason one can expect deviations from ideal osmotic behaviour, but these deviations do not imply that osmotic forces are not the controlling factors in cell water relations.

Finally, the dynamic side of water relations must be emphasized. Part of the confusion and difficulty experienced in interpreting water relations in terms of osmosis has been associated with the failure to appreciate the dynamic nature of the cell. Far too little attention has been given to the osmo-regulatory role of metabolism. Unfortunately, all too little is known regarding the way the osmotic properties of the cell are linked with other cell functions. The elucidation of this problem should provide a stimulus for future research in cell water relations.

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EXPLANATION OF PLATE A.

Fig. 1.—Thin section of Beetroot protoplast plasmolysed in 1·0M. glucose and fixed in 2% O_sO_4 at pH 7·2. Note the tonoplast (*t*) next to the vacuole (*v*) and the outer membrane (*OM*) next to the space (*s*) between the cell wall (*c.w.*) and the protoplast. Electron micrograph × 28,000.

Fig. 2.—A general view of the cytoplasmic layer in internodal cell of *Nitella* sp. Note the lamellar chloroplast (*ch*) enclosed by a membrane, several mitochondria (*m*) also enclosed by membranes, the lamellar structure (*cyt.l.*) and granular structure of the cytoplasm, and the tonoplast (*t*). Electron micrograph × 80,000.

The Honorary Treasurer, Dr. A. B. Walkom, presented the Balance Sheets for the year ended 28th February, 1955, duly signed by the Auditor, Mr. S. J. Rayment, F.C.A. (Aust.); and his motion that they be received and adopted was carried unanimously.

No nominations of other candidates having been received, the Chairman declared the following elections for the ensuing year to be duly made:

President: F. V. Mercer, B.Sc., Ph.D.

Members of Council: D. J. Lee, B.Sc.; F. V. Mercer, B.Sc., Ph.D.; S. Smith-White, B.Sc.Agr.; E. Le G. Troughton, C.M.Z.S., F.R.Z.S.; H. S. H. Wardlaw, D.Sc., F.R.A.C.I.; and A. R. Woodhill, D.Sc.Agr.

Auditor: S. J. Rayment, F.C.A. (Aust.).

A cordial vote of thanks to the retiring President was carried by acclamation.

LINNEAN SOCIETY OF NEW SOUTH WALES.

GENERAL ACCOUNT. Balance Sheet at 28th February, 1955.

LIABILITIES.	£ s. d.	£ s. d.	ASSETS.	£ s. d.	£ s. d.
Capital—			Fixed Assets—		
Amount received from Sir William Macleay during his lifetime	14,000 0 0		Commonwealth Loans, at cost	15,048 10 0	
Further sum bequeathed by his Will	6,000 0 0		Debentures:		
		20,000 0 0	Metropolitan Water, Sewerage and Drainage Board, at cost	1,694 7 6	
Contingencies Reserve		10,741 11 4	Science House (one-third share), at cost	14,835 4 4	
					31,578 1 10
Accumulated Funds		30,741 11 4	Current Assets—		
Bookbinding Account	905 1 11		Cash in hand	10 0 0	
Income Account	875 7 2		Commercial Banking Company of Sydney, Ltd.	939 19 4	
Suspense	6 0 9				949 19 4
Current Liabilities		1,786 9 10			
		£32,528 1 2			£32,528 1 2

INCOME ACCOUNT. Year Ended 28th February, 1955.

	£ s. d.	£ s. d.		£ s. d.	£ s. d.
To Salary		604 3 4	By Balance from 1953–54		111 8 3
„ Printing Proceedings	832 8 9		„ Subscriptions: 1954–55	363 6 0	
„ Printing Reprints (Parts 1–4)	232 19 6		Arrears	27 6 0	
„ Blocks	114 7 8		In advance	14 14 0	
		1,179 15 11	Associate	10 0	
„ Insurance		14 6 4			405 16 0
„ Postage	69 14 10		„ Entrance Fees		8 8 0
„ Petty Cash	23 7 11		„ Interest		554 8 7
		93 2 9	„ Science House		563 8 0
„ Audit	16 16 0		„ Sales		356 4 7
„ Printing and Stationery	85 0 6		„ N.S.W. Government Grant		175 0 0
„ Expenses	37 10 1		„ Fellowships Account (surplus income at 28th February, 1955, transferred)		320 18 9
„ Cleaning	42 2 6		„ Bank Expenses		4 15 2
„ Bank Expenses	2 11 9		„ Sale of Reprints (1953 and 1954)		586 2 6
„ Library	31 2 9		„ Donations towards printing		65 12 0
„ Blocks for colour postcards	73 17 2		„ Rent		2 4 0
		289 0 9	„ Sale of sundries		2 15 0
„ Transfer to Bookbinding Account		196 4 7	„ Library Sales		92 10 0
„ Balance to 1955–56		875 7 2	„ Postcard Sales		2 10 0
		£3,252 0 10			£3,252 0 10

AUDITOR'S REPORT TO MEMBERS.

I have examined the books of account and vouchers of the Linnean Society of New South Wales for the year ended 28th February, 1955, and certify that the above Balance Sheet and accompanying Income Account are correct and in accordance therewith, and in my opinion present the true state of the Society's affairs at 28th February, 1955, as shown by the books. Certificates of the investments have been inspected.

A. B. WALKOM,

S. J. RAYMENT, Chartered Accountant (Aust.).

LINNEAN SOCIETY OF NEW SOUTH WALES.

LINNEAN MACLEAY FELLOWSHIPS ACCOUNT.

Balance Sheet at 28th February, 1955.

LIABILITIES.	£ s. d.	ASSETS.	£ s. d.	£ s. d.
Accumulated Funds		Fixed Assets		
Amount bequeathed by Sir William Macleay	35,000 0 0	Commonwealth Loans, at cost ..	30,450 0 0	
Surplus Income Capitalized	20,097 1 7	Debentures:		
		Metropolitan Water, Sewerage and Drainage Board, at cost	16,306 14 9	
		Rural Bank of N.S.W., at cost ..	2,172 15 0	
		Loan on Mortgage	6,035 0 0	
				54,964 9 9
		Current Assets.		
		Commercial Banking Company of Sydney, Ltd.	128 5 3	
		Commonwealth Savings Bank ..	4 6 7	
				132 11 10
	£55,097 1 7			£55,097 1 7

INCOME ACCOUNT. Year Ended 28th February, 1955.

	£ s. d.		£ s. d.
To Salaries of Linnean Macleay Fellows	1,150 4 7	By Interest	1,920 18 9
„ Research and Field Expenses ..	75 0 0		
„ Balance, being Surplus Income transferred to General Account	320 18 9		
„ Capital Account	374 15 5		
	£1,920 18 9		£1,920 18 9

AUDITOR'S REPORT TO MEMBERS.

I have examined the books of account and vouchers of the Linnean Society of New South Wales for the year ended 28th February, 1955, and certify that the above Balance Sheet and accompanying Income Account are correct and in accordance therewith, and in my opinion present the true state of the Society's affairs at 28th February, 1955, as shown by the books. Certificates of the investments have been inspected.

A. B. WALKOM,
Hon. Treasurer.

S. J. RAYMENT, Chartered Accountant (Aust.),
Auditor.

Sydney, 11th March, 1955. 1st March, 1955.

LINNEAN SOCIETY OF NEW SOUTH WALES.

BACTERIOLOGY ACCOUNT.

Balance Sheet at 28th February, 1955.

LIABILITIES.	£ s. d.	£ s. d.	ASSETS.	£ s. d.	£ s. d.
Accumulated Funds.			Fixed Assets.		
Amount bequeathed by Sir William Macleay	12,000 0 0		Commonwealth Loans, at cost	15,320 0 0	
Accumulated Income Capitalized ..	6,120 0 0		Debentures:		
Research Fund	10 0 0		Metropolitan Water, Sewerage and Drainage Board, at cost	800 0 0	
		18,130 0 0			16,120 0 0
Income Account at 28th February, 1955	613 5 1		Freehold Property, at cost		3,850 0 0
Commercial Banking Company of Sydney, Ltd.	1,230 6 7		Current Assets.		
		1,843 11 8	Commonwealth Savings Bank		3 11 8
		£19,973 11 8			£19,973 11 8

INCOME ACCOUNT. Year Ended 28th February, 1955.

	£ s. d.	£ s. d.		£ s. d.
To Salary and Allowance		1,268 12 0	By Balance from 1953–54	903 4 9
„ Insurance		16 11	„ Interest	505 15 7
„ Ramsgate Property:			„ Donations	250 0 0
Insurance	5 12 6		„ Rent	260 0 0
Rates	23 0 4			
Expenses	7 13 6			
		36 6 4		
„ Balance to 1955–56		613 5 1		
		£1,919 0 4		£1,919 0 4

AUDITOR'S REPORT TO MEMBERS.

I have examined the books of account and vouchers of the Linnean Society of New South Wales for the year ended 28th February, 1955, and certify that the above Balance Sheet and accompanying Income Account are correct and in accordance therewith, and in my opinion present the true state of the Society's affairs at 28th February, 1955, as shown by the books. Certificates of the investments have been inspected.

S. J. Rayment, Chartered Accountant (Aust.),
Auditor.

Sydney, 11th March, 1955.

A. B. Walkom,
Hon. Treasurer.

1st March, 1955.

THE *CULEX PIPIENS* GROUP IN SOUTH-EASTERN AUSTRALIA. IV.

CROSSBREEDING EXPERIMENTS WITHIN THE CULEX PIPIENS GROUP.

By N. V. Dobrotworsky, Georgina Sweet Fellow in Economic Entomology, University of Melbourne.

(Three Text-figures.)

[Read 30th March, 1955.]

Synopsis.

Crossbreeding experiments have been made between five strains of *C. pipiens* form *molestus* Forskal and between these strains and *C. fatigans* Wied. These crosses were fully fertile except when a Melbourne strain of *molestus* was involved. Reciprocal crosses of this strain with other strains of *molestus* and with *fatigans*, and also back crosses of F1 males to the paternal stocks, were abortive; the eggs developed but failed to hatch.

C. globocoxitus Dobr. was crossed with other members of the *pipiens* group. Reciprocal crosses of *globocoxitus* with *molestus* and *fatigans* and also back crosses of F1 males with the paternal stocks were sterile.

An account is given of the isolating mechanisms operating between members of the *C. pipiens* groups and the problems of speciation in this group are discussed.

Descriptions are given of the hybrids between *globocoxitus* and other members of the group.

Previous papers in this series (Dobrotworsky, 1952; Dobrotworsky and Drummond, 1953) dealt primarily with the morphological and biological characteristics of the *Culex pipiens* group in Australia. Some account was given of their capacity for interbreeding and this phase of the work has now been extended to a study of experimental crossing between various strains of *Culex pipiens* form *molestus* Forskal, between these strains and *Culex fatigans* Wied. and between *Culex globocoxitus* Dobr. and other members of the group.

Material and Methods.

Laboratory strains of *C.p. molestus* were established from the following localities (Dobrotworsky, 1954): Moe, 50 miles south-east of Melbourne (Strain *Mo*); Yarram, 100 miles south-east of Melbourne (Strain *Ya*); Point Lonsdale, 40 miles south of Melbourne (Strain *Lo*); Seymour, 50 miles north of Melbourne (Strain *Se*). In addition a Melbourne strain (Strain *Me*) was established in 1952 from 38 autogenous egg rafts laid by mosquitoes reared from pupae collected in the University Grounds. All these strains have been maintained autogenously.

Culex fatigans material was also provided by a laboratory colony. This was established in 1953 from a single female collected at Mildura.

It was, however, not possible to establish colonies of the other two members of the *pipiens* groups, *C. pipiens australicus* and *C. globocoxitus*, because, in the laboratory, *australicus* will not mate and *C. globocoxitus* has a very high larval mortality. Adults of these two forms were reared, as required, from larvae collected in Melbourne suburbs.

In experiments involving *fatigans* males, the mating cages were of 3825 cubic inches capacity; for other crosses, they were of 1000 cubic inches. Normally, equal numbers of males and females were used and were left together for 48 hours. However, in attempted crosses between *fatigans* or *australicus* females and *globocoxitus* males, and again in crosses between *globocoxitus* females and *molestus* or *fatigans* males, a great excess of males was used and the mating period was extended up to seven days.

All the mosquitoes used in these experiments were reared from pupae in separate tubes, and females, prior to oviposition, were again individually isolated.

Egg rafts were examined 24 hours after hatching commenced and separate counts made of the number of eggs which had hatched, the number containing embryos which had failed to emerge, and the number which had failed to develop at all. Eggs of the second category were kept for observation for a further 48 hours. Females which either died before oviposition, or laid totally infertile rafts, were dissected for examination of their spermathecae. The results of experiments in which insemination did not occur have been excluded from the calculations presented in the tables.

Crosses between different strains of molestus.

Crosses between the strains *Lo*, *Mo*, *Ya* and *Se* were fully fertile in both directions (Table 1, Text-fig. 1); strain *Me*, however, was fully fertile only with strain *Se*. Crosses between *Me* females and males of all the other strains were fertile, but reciprocal crosses,

TABLE 1.

Crossing between Different Strains of molestus.

Female.	Male.	Number of		Percentage Hatch.	Percentage Unhatched.	
		Egg Rafts.*	Eggs.		With Embryo.	Without Embryo.
Me	Se	5	384	88·8	5·0	6·2
Me	Lo	20	1419	97·8	0·0	2·2
Me	Ya	6	310	94·9	1·6	3·5
Me	Mo	4	287	97·6	0·3	2·1
Se	Me	3	118	82·2	0·0	17·8
Se	Lo	5	282	98·2	0·4	1·4
Se	Ya	5	360	90·3	1·9	7·8
Se	Mo	7	400	97·2	0·5	2·3
Lo	Me	20	1211	0·0	83·1	16·9
Lo	Se	6	346	99·4	0·3	0·3
Lo	Ya	5	255	71·8	1·2	27·0
Lo	Mo	8	368	96·5	0·0	3·5
Ya	Me	11	397	10·8	65·2	24·0
Ya	Se	6	354	94·2	0·6	4·2
Ya	Lo	9	429	97·7	0·0	2·3
Ya	Mo	7	232	96·1	2·2	1·7
Mo	Me	16	531	0·0	69·9	30·1
Mo	Se	4	202	98·3	0·0	1·5
Mo	Lo	4	107	72·0	5·6	22·4
Mo	Ya	10	302	89·4	4·3	6·3

Me=Melbourne strain; Se=Seymour strain; Lo=Point Lonsdale strain; Ya=Yarram strain; Mo=Moe strain.

* All egg rafts were laid autogenously.

except with *Se*, failed to yield viable offspring. In these experiments it was found that the eggs developed to an advanced stage but that the larvae failed to emerge. The only exception was provided by one *Ya* × *Me** mating in which all the embryonated eggs hatched; most of the larvae, however, died during their development.

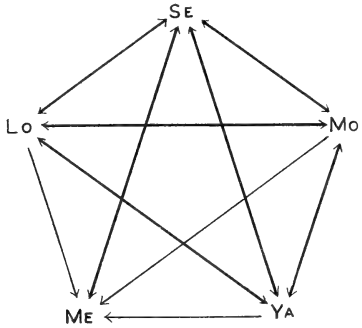
The reciprocal crosses were, then, infertile, but for the later discussion of results it is convenient to make a distinction between infertility due to a failure of larvae to emerge from eggs and infertility due to a failure of the eggs to develop after insemination. Crosses of the first type will be described as abortive, those of the second type, as sterile.

Backcrosses to the parental strains were fertile in most cases (Table 2). However, crosses of hybrid males *Me Mo* and *Me Lo* with the paternal strains were frequently abortive; only a few rafts yielded larvae which completed their development.

* Following the usual convention the female parent is written first.

As would be expected, crosses between *Ya Mo* and *Mo Lo* females and *Me* males were abortive; the few larvae which emerged died in the first instar. The reciprocal crosses were fertile; only a few eggs failed to hatch.

The percentage of sterile eggs in *Mo* × *Me* crosses was nearly twice that in *Lo* × *Me* crosses and a similar difference between the *Mo* and *Lo* strains in relation to *Me* is seen in the backcrosses referred to above. Evidently strain *Me* is genetically closer to *Lo* than to *Mo*.



Text-figure 1.—Diagram of the crossing between different strains of *molestus*.

Crosses between C. fatigans *and various strains of* molestus.

It is a striking fact that the *Me* strain of *molestus* behaves differently from all the other strains when crossed with *C. fatigans*. When *Me* females were used the crosses were fertile, but reciprocal crosses were invariably abortive. So also were backcrosses of *m f* males with *fatigans* females.

TABLE 2.

Backcrossings of molestus *Strains.*

Female.	Male.	Number of		Percentage Hatch.	Percentage Unhatched.	
		Egg Rafts.*	Eggs.		With Embryo.	Without Embryo.
MeLo	Lo	14	613	95·0	0·8	4·2
MeLo	Me	17	1316	66·5	7·6	25·7
Lo	MeLo	13	728	38·3	46·3	15·4
Me	MeLo	10	810	83·8	3·2	13·0
MeMo	Me	8	469	78·2	4·1	17·7
Mo	MeMo	10	434	9·0	59·7	31·3
Me	MeMo	6	408	93·9	2·0	4·1
YaMo	Me	19	819	0·5	79·8	19·7
Me	YaMe	24	1158	83·2	6·9	9·9
MoLo	Me	4	134	0·7	90·3	9·0
Me	MoLo	4	178	95·0	2·8	2·2
SeMe	Lo	11	716	98·0	0·4	1·6
Lo	SeMe	5	213	84·0	3·3	12·7
MeSe	Lo	3	91	97·8	0·0	2·2
Lo	MeSe	5	368	91·0	1·3	7·7

Me = Melbourne strain; Se = Seymour strain; Lo = Point Lonsdale strain; Ya = Yarram strain; Mo = Moe strain.

* All egg rafts were laid autogenously.

TABLE 3.

Crossing between C. fatigans *and Different Strains of* molestus.

Female.	Male.	Number of		Percentage Hatch.	Percentage Unhatched.	
		Egg Rafts.*	Eggs.		With Embryo.	Without Embryo.
			Me strain of *molestus*.			
molestus	*fatigans*	11	607	93·0	1·4	5·6
fatigans	*molestus*	15	774	0·0	81·8	18·2
mf	*mf*	20	1560	75·1	7·9	17·0
mf	*fatigans*	5	396	95·1	0·5	4·4
mf	*molestus*	4	352	50·0	10·5	39·5
fatigans	*mf*	11	643	0·0	74·8	25·2
molestus	*mf*	6	426	57·1	14·7	28·2
			Other strains of *molestus*.			
molestus	*fatigans*	5	368	96·2	0·6	3·2
fatigans	*molestus*	25	1603	95·4	0·4	4·2
mf	*mf*	10	825	96·9	0·8	2·3
mf	*fatigans*	5	548	97·6	1·5	0·9
mf	*molestus*	6	419	98·6	0·5	0·9
fatigans	*mf*	5	320	86·3	3·4	10·3
molestus	*mf*	10	479	83·7	9·0	7·3
fm	*fm*	6	505	95·9	1·6	2·6
fm	*fatigans*	7	425	97·7	0·2	2·1
fm	*molestus*	7	490	97·8	0·2	2·0
fatigans	*fm*	8	461	65·7	13·7	20·6
molestus	*fm*	6	285	64·0	2·0	34·0

* All females were fed on human blood.

Backcrosses with *molestus* showed a substantial reduction in fertility and there was also some reduction in F1 matings. Larvae which emerged developed normally.

In contrast to these results, crosses between *C. fatigans* and the other strains of *molestus* (particularly *Mo*) were fully fertile in both directions. F1 matings and backcrosses were also characterized by high fertility; the only reduction in fertility occurred in backcrosses of *f m* males with females of the parental forms; some of these crosses were fertile but others gave only a low hatch of eggs.

Crosses between C. globocoxitus *and other members of the* C. pipiens *group.*

Males of *C. globocoxitus* readily mate with *molestus* females and apparently make no distinction between them and females of their own species (Table 4).

TABLE 4.

Preferential Mating within the C. pipiens *Group.*

Male.	Number of Females Fertilized.					
	globocoxitus.	*molestus.*	*fatigans.*	*australicus.*	*molestus*-Me.	*molestus*-Lo.
globocoxitus ..	10/20	9/20				
molestus ..	0/20	19/20				
globocoxitus ..	18/20		1/20			
fatigans ..	0/20		18/20			
globocoxitus ..	8/20	10/20	2/20	0/20		
molestus-Me ..					14/20	12/20

These matings were highly fertile. Reciprocal crosses, however, were achieved only with difficulty and were almost completely infertile—95·8 per cent of the eggs did not develop and the few larvae which emerged died in the first instar (Table 5).

Backcrosses of *m g* males with *globocoxitus* females were likewise highly infertile: 85·6 per cent of the eggs failed to develop. However, in this cross, although most of the larvae died in the first instar, a few yielded adults. In crosses between *molestus* females and *m g* males, there was some reduction in fertility, but backcrosses involving *m g* females with *molestus* males were highly fertile. The larvae from these crosses were vigorous and developed normally.

TABLE 5.

Crossing between C. globocoxitus *and Other Members of the* C. pipiens *Group.*

Female.	Male.	Number of		Percentage Hatched.	Percentage Unhatched.	
		Egg Rafts.*	Eggs.		With Embryo.	Without Embryo.
molestus	*globocoxitus*	23	1448	98·6	0·1	1·2
globocoxitus	*molestus*	6	435	1·3	2·8	95·8
mg	*mg*	16	1267	60·6	7·9	31·5
mg	*globocoxitus*	8	509	86·4	7·6	6·0
mg	*molestus*	13	1126	89·3	2·3	8·4
globocoxitus	*mg*	9	659	5·5	8·9	85·6
molestus	*mg*	14	781	74·8	4·5	20·7
fatigans	*globocoxitus*	12	936	91·1	1·0	7·9
globocoxitus	*fatigans*	1	79	0·0	0·0	100·0
fg	*fg*	9	743	95·4	1·6	3·0
fg	*globocoxitus*	11	689	89·4	1·4	9·2
fg	*fatigans*	6	402	94·3	0·4	5·4
globocoxitus	*fg*	2	128	0·0	0·0	100·0
fatigans	*fg*	11	743	88·1	0·3	11·6
australicus	*globocoxitus*	13	870	99·1	0·2	0·7
ag	*globocoxitus*	5	335	96·1	0·3	3·6

* All the females were fed on human blood.

Rather similar results have been obtained in crosses between *C. globocoxitus* and the two remaining members of the *C. pipiens* group. Although *globocoxitus* males show a strong, or total, preference for intra-specific mating, they will, in the absence of choice, mate with females of *fatigans* and *australicus* (Table 4); these matings are highly fertile.

Reciprocal crosses with *fatigans* are totally infertile; in such crosses there is almost complete sexual isolation. In an experiment repeated seven times, ten *globocoxitus* females were caged with 30–50 *fatigans* males for periods of up to seven days; in all, only one female was fertilized and her eggs failed to develop. Backcrosses were fully fertile except those involving *globocoxitus* females which were completely sterile. Many of these crosses, however, were difficult to achieve; *m f* males did not readily mate with *m f* females, and only exceptionally with *globocoxitus*; *fatigans* males tended to ignore hybrid females, and, even when no choice was given, only six out of fifty were inseminated. In the corresponding experiments with *molestus* the males did not make any distinction between hybrids and their own females when caged together.

Experimental crosses between *globocoxitus* and *australicus* were restricted by the fact that *australicus* itself, and *a g* hybrids, are eurygamous. The two possible crossings were fully fertile.

These experiments have demonstrated three levels of fertility between members of the *pipiens* group:

1. Reciprocal crosses and backcrosses, fertile—most strains of *molestus* and these strains with *fatigans*.

2. Reciprocal crosses and backcrosses of hybrid males to paternal stock, abortive—*Me* strain of *molestus* with most other strains and with *fatigans*.

3. Reciprocal crosses and backcrosses of hybrid males to paternal stock, sterile—*globocoxitus* with *molestus* and *fatigans*.

Discussion.

For the old school of taxonomist, the species was a static conception based on the degree of morphological distinctness. The study of geographical variations, however, has shown that some well known "species" are actually groups of species indistinguishable morphologically. Morphological definition is satisfactory for the monotypic species, but it is clearly inadequate for the polytypic.

In modern taxonomy, the species is a dynamic conception; it is the product of the evolutionary process, and its definition is based on reproductive isolation of natural populations. This was formulated by Mayr (1942) as follows: "Species are groups of actually, or potentially, interbreeding natural populations which are reproductively isolated from other such groups." It is only in such isolation that new forms can develop.

Of various isolating mechanisms, the most important is sexual isolation; between species this is usually complete; between races or strains of the same species it is absent, as a rule. If two or more closely related forms are found in the same area, without the occurrence of intermediates, they must be sexually isolated and therefore must be distinct species. If two populations occupy neighbouring geographical or ecological areas, and produce intermediates where they overlap, they are treated as subspecies.

From the nature of the problem it is impossible to provide a definition of species which will cover all cases and Mayr's cannot always be applied rigidly. We know, for example, that *globocoxitus* and *molestus* are, as a rule, ecologically isolated (see below). Occasionally, however, they utilize the same breeding sites and they may then interbreed. Previously only a few hybrids had been collected (Dobrotworsky, 1953), but in 1953 and 1954 a permanent breeding place of *globocoxitus* was found to harbour also *molestus* in the winter; during the period of joint occupancy, hybrids were very common; they were absent during the summer. In the absence of a permanent population of intermediates, *globocoxitus* must be regarded as a distinct species.

In many cases, interbreeding in nature between closely related forms may be difficult to detect, particularly if they are similar morphologically. The first approach must then be through laboratory crossbreeding. The results of such experiments are not necessarily conclusive, since the conditions differ from those in nature, but they may contribute to the solution of difficult taxonomic problems; they also provide the information necessary for an analysis of mechanisms which determine the degree of reproductive isolation.

For the Australian members of the *pipiens* group these mechanisms are:

1. *Ecological isolation.*—*globocoxitus* and *australicus* are ecologically isolated from *molestus* and *fatigans*. The first two are rural mosquitoes breeding mainly in clear ground water and swamps; the second two usually occur in the vicinity of human dwellings and breed in ground pools of artificial containers, with a preference for polluted water. This isolation is not complete because *globocoxitus* and *australicus* sometimes breed in suburban sites in company with *molestus* or *fatigans*. As mentioned above, *globocoxitus* and *molestus* may then interbreed but no *australicus* hybrids have been found.

2. *Sexual isolation.*—No mating preference exists between *fatigans* and *molestus*, or between the various strains of *molestus*. Between *molestus* and *globocoxitus* there is a one-sided sexual preference; males of *globocoxitus* inseminate females of both species indiscriminately, but *molestus* males ignore *globocoxitus* females. Between *globocoxitus* on the one hand and *fatigans* and *australicus* on the other, there is almost complete sexual isolation due to mating preferences.

The isolation of *australicus* from all the other members of the group is largely due to the fact that it is eurygamous; mating occurs in flight, and resting females, in cages, generally resist stenogamous males attempting to copulate.

3. *Mechanical isolation.*—This has been occasionally observed between *globocoxitus* males and *australicus* females. Coupling takes place with difficulty and some pairs are not able to separate.

4. *Gametic isolation.*—Males of *fatigans* and *molestus* will inseminate *globocoxitus* females, but the eggs, with few exceptions, fail to develop. Similar results were obtained in backcrosses of F1 males ($m\,g$ and $f\,g$) with *globocoxitus*.

5. *Hybrid inviability.*—The few larvae which hatched from the *globocoxitus* × *molestus* crosses and from the backcrosses ($g \times m\,g$) died in the first instar. The other notable example of hybrid inviability is seen in the crosses between *molestus* males of the Melbourne strain and females of the other strains, and of *fatigans*.

Many workers, in different parts of the world, have investigated crossbreeding between members of the *pipiens* group, particularly *pipiens*, *molestus* and *fatigans*. One of the most interesting results of this work is the discovery that, while crosses between these forms are commonly fertile, crosses between geographical strains of *molestus* may be partly sterile (Marshall, 1938; Roubaud, 1941, 1945; Ghelelovitch, 1952; Shute, 1953; Laven, 1951, 1953).

Laven, who has investigated this phenomenon in most detail, suggests that within *molestus* there may exist "several systematic units not yet recognised".

Laven explains the partial sterility between strains as an effect of the maternal cytoplasm, a view which Smith-White (1950) had previously put forward to account for results of crossings within the *Aëdes scutellaris* group. The basic features of these crosses, which have led to the application of the theory of the cytoplasmic factors, are non-reciprocal fertility and the sterility of backcrosses between hybrid males and females of the paternal form. The eggs either fail to develop or, if they develop, the larvae either do not hatch or are non-viable. It is believed that the egg cytoplasm is inimical to the genome of the other partner in the cross.

The results, recorded above, of crosses between the Melbourne strain of *molestus* and the other strains are in harmony with Laven's view. So also are the results of crosses: *Me* strain of *molestus* × *fatigans*, *molestus* × *globocoxitus* and *fatigans* × *globocoxitus*. However, in the first two of these, the reduced fertility in F1 crosses indicates that there is also some genic disbalance.

From these experiments it appears that the intensity of the cytoplasmic effect depends on the closeness of the relationship between the participants in the cross. When they are closely related (e.g., strains of *molestus*) the eggs develop but the larvae fail to emerge; the shell, a maternal tissue, is possibly a mechanical barrier. With more distantly related forms (e.g. *molestus* and *globocoxitus*) the eggs do not develop at all.

The analysis of isolating mechanisms and inter-fertility has shown that there are different levels of speciation within the *C. pipiens* group. *C. globocoxitus* is reproductively isolated; though closer to *molestus* than to *fatigans*, it is specifically distinct from both. Between *fatigans* and *molestus* there appear to be no isolating mechanisms and since they have been repeatedly recorded as interbreeding in nature and can establish independent hybrid populations they cannot be regarded as separate species.

The Victorian strains of *molestus* cannot be regarded as a complex of sibling species for, although there are some genetical differences between them, there is no sexual isolation; the strains would certainly interbreed in nature. It is more likely that *molestus* provides an example of the alternative situation postulated by Kitzmiller (1953). It appears to be undergoing rapid expansive evolution, but the genetical changes have not, as yet, been accompanied by detectable morphological and/or physiological differences.

One outstanding problem in the taxonomy of the *pipiens* group is the relationships of *molestus* and *fatigans* to *pipiens*, s. st. Some of the contradictions in the results of crossbreeding experiments between these forms can be attributed to a failure to make a distinction between the North American *pipiens* and the European. The opinion that

they must be treated separately (Dobrotworsky and Drummond, 1953, p. 135) is reinforced by the recent work of Micks (1954) on the paper chromatography of these forms.

Structure of C. globocoxitus *hybrids.*

Descriptions of *pipiens* × *fatigans* hybrids have been given by many workers (Weyer, 1936; Sundararaman, 1949; Rozeboom, 1951; etc.) and only *globocoxitus* hybrids will be described here. The F1 hybrids from crosses of *globocoxitus* and *molestus*, *fatigans* or *australicus* are structurally intermediate between the parent forms. This is most evident in the male genitalia because of its distinctive structure in *globocoxitus*. The coxites of the F1 hybrids are slightly swollen and the bunch of setae on the inner face is reduced. The rods and setae on the sub-apical lobe undergo a variety of changes, particularly in setae accompanying the leaf; seta *i*, which is present only in *globocoxitus*, is inherited only by *australicus* × *globocoxitus* hybrids. The shape of the mesosome is also important for distinguishing the hybrids.

The F2 generation consists mainly of intermediates, but a few specimens were similar to one or other of the parental forms. The results of backcrosses were similar except that there was a smaller proportion of intermediates.

Description of the adult hybrids.

molestus × *globocoxitus*.—The F1 males are intermediate. The length of the palps is variable; the shaft has long hairs as in *molestus*. The sub-apical lobe of the coxite bears three proximal rods (Text-fig. 2); the number of setae accompanying the leaf varies from one to three; the seta *i* is always single. The setae on the inner face of the coxite are few in number and short. The dorsal processes of the mesosome are variable; in some specimens they are like those of *globocoxitus*, in others the tip is rounded or has a small apical cavity. The number of hairs on each lateral lobe of the ninth tergite varies from four to fourteen with a mean of eight.

The females show more resemblance to *globocoxitus*. The abdomen is usually black above with wide basal bands; the lateral spots are usually duller than in *globocoxitus*. Patches of black scales on the venter are inconspicuous or absent.

The F2 consists mostly of intermediates; but some specimens are indistinguishable from the parental species.

molestus globocoxitus × *molestus*.—The offspring are almost identical with *molestus*, but some males have a few long hairs on the inner face of the coxites. One male was distinguished by very long palps; the first four segments were longer than the proboscis.

molestus × *molestus globocoxitus*.—The majority are intermediate. A few males are similar to *globocoxitus* and others have short palps as in *globocoxitus*, but genitalia identical with that of *molestus*.

fatigans × *globocoxitus*.—The F1 males are intermediate. The first four segments of the palps are shorter than the proboscis; the shaft has long hairs as in *fatigans*. The rods and setae on the sub-apical lobe of the coxites resemble those of *fatigans*. In the mesosome the dorsal processes are like those in *fatigans*, the ventral processes and the DV/D ratio are intermediate. Each lateral lobe of the ninth tergite bears four–six hairs.

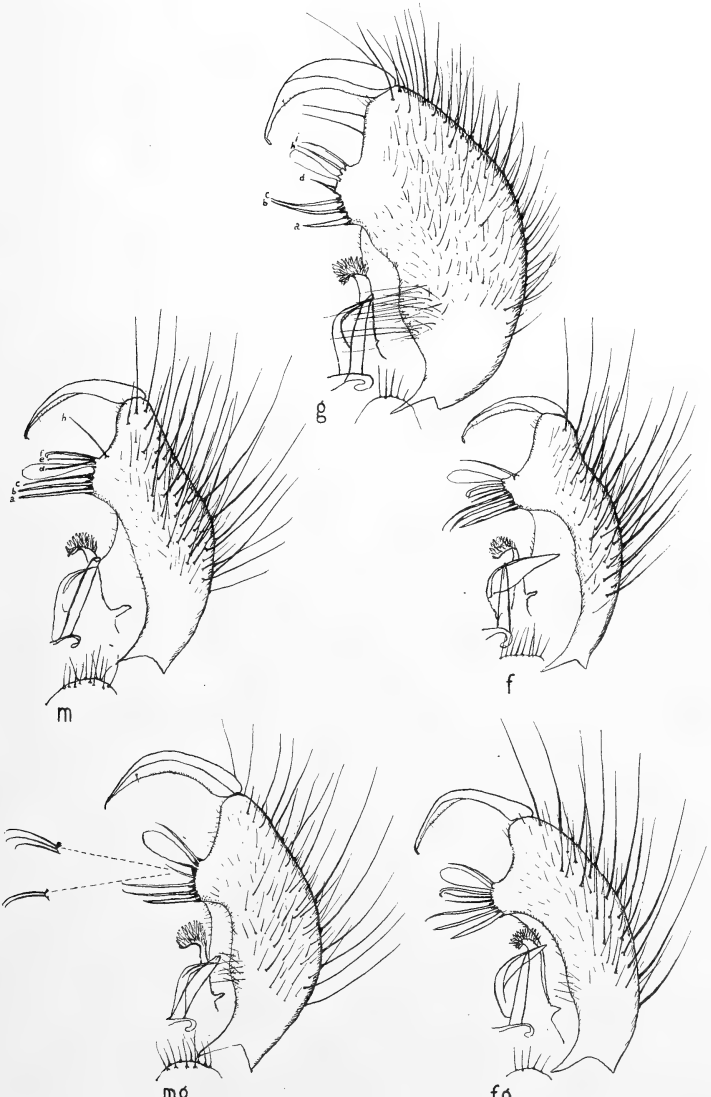
The F1 females tend to resemble *fatigans*. The abdominal bands are usually more or less constricted laterally; on the venter patches of black scales may be present or absent.

The F2 tends towards *fatigans*; the male genitalia is similar, but in some the DV/D radio is intermediate. A few males are similar to *globocoxitus*.

fatigans globocoxitus × *fatigans*.—Variable but tending towards *fatigans*. A few males were similar to *globocoxitus*.

fatigans globocoxitus × *globocoxitus*.—Variable but tending towards *globocoxitus*. The ventral processes of the mesosome are intermediate. The abdominal bands in the females are usually wide, but in a few specimens are constricted laterally as in *fatigans*. On the venter, patches of black scales may be present or absent.

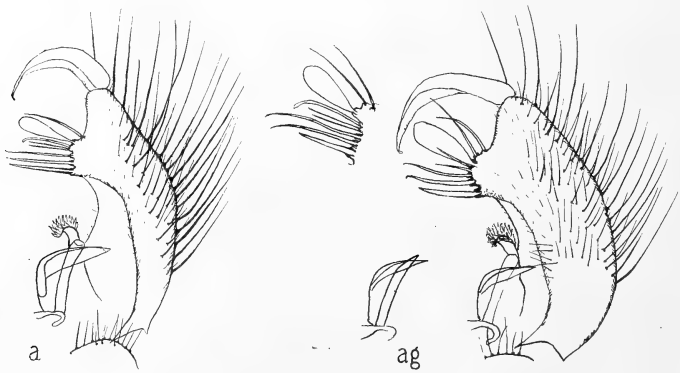
fatigans × *fatigans globocoxitus*.—The males are intermediate, but tend towards *fatigans*; in some the DV/D ratio is intermediate. The females are similar to *fatigans*.



Text-figure 2.—Male genitalia. *g—globocoxitus*, *m—molestus*, *f—fatigans*, *mg—molestus* × *globocoxitus*, *fg—fatigans* × *globocoxitus*; *a-c*—proximal rods, *d-i*—setae.

australicus × *globocoxitus*.—The F1 is intermediate, but tends towards *australicus*. The male palps are similar to those of *australicus*, but the first four segments are shorter than the proboscis and the long hairs are less numerous. The genitalia are intermediate (Text-fig. 3); the sub-apical lobe of the coxites bears three proximal rods of which *a* is intermediate, while *b* and *c* are similar to those of *australicus*; the group of setae accompanying the leaf usually consists of two setae, though in one male this group was similar to that of *australicus*; the seta *i* is present as in *globocoxitus*. The dorsal processes of the mesosome are variable; the ventral processes are like those in *australicus*.

The proboscis of the females is usually pale ventrally; only two females had black scales ventrally at the tip. Only one female had postspiracular scales. The abdominal bands are variable; in some they resemble those of *globocoxitus*, but in most the bands are separated from the lateral spots on the second–fifth tergites, as in *australicus*. Patches of black scales on the venter are variable in size but always present.



Text-figure 3.—Male genitalia. *a*—*australicus*, *ag*—*australicus* × *globocoxitus*.

australicus globocoxitus × *globocoxitus*.—Intermediate. The first four segments of the male palps almost equal the length of the proboscis. The distal half of the shaft bears ten–fourteen long hairs. The coxite is similar to that of *globocoxitus*, but the hairs on the inner face are always shorter and less dense. The mesosome is intermediate.

The females are variable; some are intermediate, others are indistinguishable from *globocoxitus*. The patches of black scales on the venter are less prominent and may be absent.

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A NOTE ON THE FAECAL FLORA OF SOME ANTARCTIC BIRDS AND MAMMALS AT MACQUARIE ISLAND.

By J. S. Bunt,* Australian National Antarctic Research Expedition.

[Read 30th March, 1955.]

Synopsis.

An account is given of the aerobic bacteria found in the faeces of various antarctic birds and one mammal at Macquarie Island. *Escherichia coli* (Migula) Castellani and Chalmers was found in six species of birds and the seal elephant (*Morunga elephantina*). *Bacillus* and *Micrococcus* species were also fairly common. The faeces from single specimens of two avian species appeared to be completely sterile, possibly the result of microbial antagonisms within the rectum.

Introduction.

Since the inception of antarctic exploration, at least five expeditions have studied the bacteria of the alimentary canal, natural excretions and wounds of the various mammals, birds and fish which inhabit those regions. The first work of this nature appears to have been undertaken independently by Ekelöf (1908) and Gazert (1901–3). During 1903–5, Charcot collected further material which was examined by Tsiklinsky (1908). Later, McLean (1919) published the results of his studies from 1911–14 and Harvey Pirie (1912) his findings whilst with a separate expedition during the same period.

The results presented here were obtained from material gathered by the author as a member of the 1951–2 Australian National Antarctic Research Expedition to Macquarie Island. The only land mass in a vast expanse of ocean, Macquarie Island is most important as a breeding ground for seals, penguins and antarctic birds of flight. Approximately 24 species inhabit the island during the summer months. Of these, 16, including the most prominent types, have been used in this study. Bacterial isolates were obtained by normal plating techniques and maintained for further examination on return to Australia.

Results.

A number of practical difficulties associated with unavoidably imperfect laboratory conditions at Macquarie Island resulted in the loss of many of the organisms originally isolated. The findings are summarized in Table 1. *Escherichia coli* was isolated from approximately half the species examined. No other types were found in the faeces of the seal elephant and the king penguin. Of the coliforms examined, five gave the reactions characteristic of *E. coli* type 1, and two gave those characteristic of *E. coli* type 2. The species of *Bacillus* isolated from the Royal penguin and the Gentoo penguin were morphologically and culturally identical. The diving petrel contained the most diverse faecal flora. No bacteria could be isolated from the faeces of the white-headed petrel or the dove-prion. The cultures placed under the general heading, "aerobic non-sporing rods", died out before they could be studied in any detail.

In addition to isolating faecal organisms, mixed cultures were prepared from wound pus and the mucous exudation from the nose of a bull seal elephant, but they did not retain their viability. However, smears were prepared from the original samples and also from the cultures when first isolated.

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In the pus smear were found Gram-negative rods, approximately $0{\cdot}7 \times 3{\cdot}0\mu$, usually occurring singly. Bacteria with the same morphology were also found giving a positive Gram reaction. Less frequently, small Gram-positive diplococci and Gram-negative, non-sporing rods, more than 10μ long and $0{\cdot}7\mu$ wide, were observed.

Infections of the nasal passages were found to be very prevalent. Small Gram-positive rods, Gram-positive micrococci and diplococci were common in mucus smears.

TABLE 1.

Bacteria Isolated from Faeces of Birds and Mammals at Macquarie Island.

Source.	*E. coli* Type.*		*Bacillus* spp. Gram Reaction.		Aerobic Non-sporing Rods.		*Micrococcus.*
	1	2	Positive.	Variable.	Gram-Positive.	Gram-Negative.	
Seal elephant (*Morunga elephantina*)	x						
King penguin (*Aptenodytes patagonica*)	x						
Royal penguin (*Eudyptes schlegeli*)	x			x			
Rockhopper penguin (*Eudyptes cristatus*)			x				
Gentoo penguin (*Pygoscelis papua*)				x	x	x	
Black-browed albatross (*Thalassarche melanophris*)					x		x
Giant petrel (*Macronectes giganteus*)	x				x	x	
Sooty shearwater (*Puffinus griseus*)			x			x	
Southern skua gull (*Catharacta skua lonnbergi*)		x	x				
Dominican gull (*Larus dominicanus*)		x				x	
Macquarie Island shag (*Phalacrocorax albiventer purpurascens*) ..					x	x	x
Grey duck (*Anas superciliosa*) ..			x			x	x
Diving petrel (*Pelecanoides georgicus*)			xx		x	x	x
Bar-tailed godwit (*Limosa baueri*) ..	x						x

White-headed petrel (*Pterodroma lessoni*) and dove-prion (*Pachyptila desolata*): faeces apparently bacteria-free.
* Topley and Wilson (1946).

DISCUSSION.

McLean (1919) reported that *E. coli* had not been recorded from antarctic petrels either by himself or by previous workers, and hoped that the presence or absence of this organism might be established at some future date. The writer has isolated *E. coli* type 1 from the faeces of a giant petrel and an organism with the morphology and colonial characters of *E. coli* from a diving petrel. No bacteria were found in the faeces of a white-headed petrel. As the evidence available would suggest that *E. coli* is not an invariable constituent of the intestinal flora in any animal, it is probable that one should examine a number of specimens of any one species before concluding the general absence of coliform or any other group of organisms.

It is interesting to note that Oppenheimer and Kelly (1952) have isolated *E. coli* from the intestine of a wild sea lion (*Zalophus californianus*). Apparently they were

not aware of the earlier antarctic studies reviewed in this paper, since their examination was conducted especially to discover whether this organism might be present in marine mammals under natural conditions.

The reported sterility of the faeces from a number of antarctic birds and mammals is particularly interesting. For convenience, the results from several investigators are presented in Table 2. It will be seen that a wide range of species is reported to have no bacterial flora in the intestine. However, since seven of these species have also been found not to be sterile by one or more investigators, it does not follow that sterility of the faeces in one specimen is indicative of sterility in that species as a whole. Although

TABLE 2.

Faeces of Various Antarctic Birds and Mammals reported to be Bacteria-free.

Harvey Pirie (1912).	Gazert (1901–03).	Ekelöf (1908).	McLean (1919).	Bunt.
tern. cape pigeon. Wilson petrel. sheath bill.	tern. snow petrel. antarctic petrel. king penguin. *Priofinus* sp.	tern. Adelie penguin. gentoo penguin. cormorant.	tern. prion. silver-grey petrel. Ross seal.	dove prion. white-headed petrel.

it may be suspected that failure to obtain bacterial growth could be due to ineffective cultural treatment, the writer has collected some evidence to show that this may not always be the case, viz., the apparently bacteria-free faeces from a white-headed petrel were found to contain large numbers of yeast-like bodies or protozoa. These may have been causing the complete inhibition of bacteria, either by direct competition for nutrients or by the production of antibiotic substances. Unfortunately, it has not been possible to test this hypothesis. Certainly, it does not seem reasonable to assume that the absence of bacteria in the rectum could be due to a supposedly sterile, or almost sterile diet, as has been suggested in the case of certain antarctic birds by McLean (1919).

Acknowledgements.

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CHROMOSOME NUMBERS AND POLLEN TETRAD SIZE IN THE WINTERACEAE.

By A. T. Hotchkiss, Department of Botany, University of Sydney.

(Plate i; five Text-figures.)

[Read 30th March, 1955.]

Synopsis.

The chromosome number of the four species of *Drimys* growing in New South Wales has been determined. Measurements of pollen tetrads from thirty-six species of the six genera of the Winteraceae are tabulated here. Centrifugal development of the stamens in *Drimys* is noted.

Chromosome Number.

There are six genera in the Winteraceae according to the recent treatment of this family by Smith (1943*b*). The Old World representatives of the genus *Drimys* all belong in the Section *Tasmannia* with about 36 species which extend from the Philippines through eastern Malaysia and eastern Australia to Tasmania. These are separated by Smith (1943*a*) from the American Section *Wintera* with four species scattered from Mexico to Cape Horn. Vickery (1937) reviewed the genus *Drimys* in south-eastern Australia, and described two new species and a new variety. Smith (1943*b*) recognized a total of six species in Australia—*D. membranea*, *D. insipida*, *D. purpurascens*, *D. stipitata*, *D. lanceolata*, *D. vickeriana*. The other five genera, *Belliolum*, *Bubbia*, *Exospermum*, *Pseudowintera* and *Zygogynum*, are found only in the Australasian area. Of these, only the genus *Bubbia* occurs in Australia.

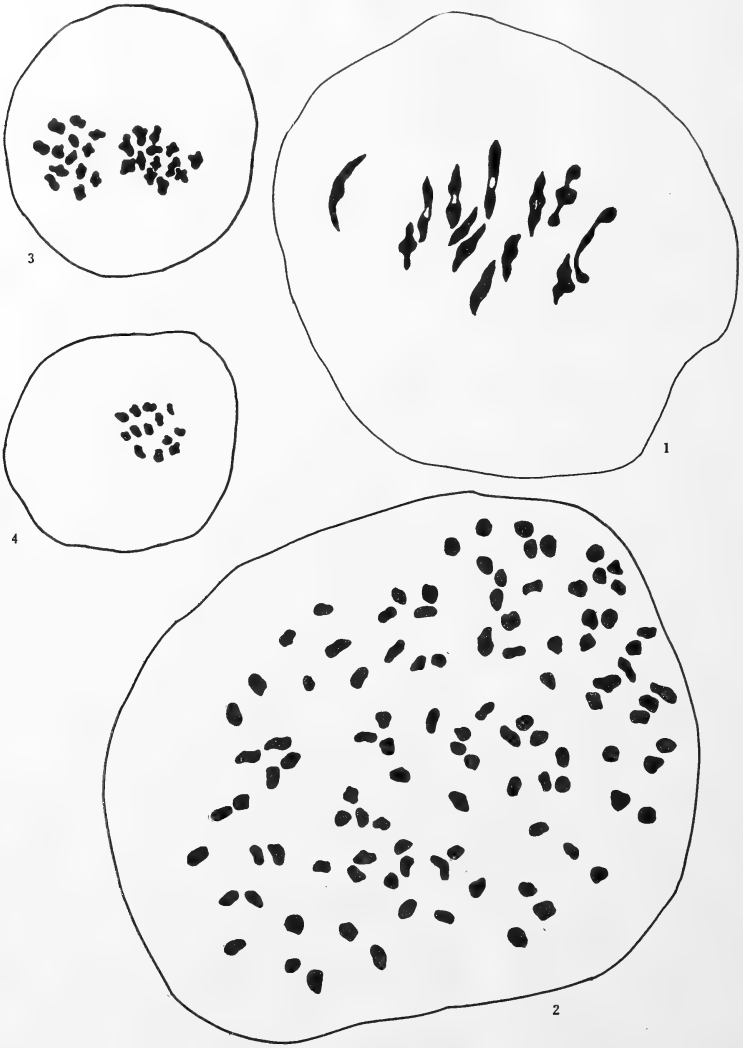
Chromosome counts have been made on the four species of *Drimys* found in New South Wales. Herbarium specimens to be distributed have been collected for these four species. *D. lanceolata* was collected in the Mt. Kosciusko area, New South Wales, from plants growing on the slope between the road and the Snowy River about half a mile from Charlotte's Pass during January, 1954. A single count was made in the field camp. *D. insipida* was collected at Wentworth Falls, New South Wales, from plants growing near the lower falls during August, 1954. *D. stipitata* was collected in Rocky Creek Gully, Dorrigo, New South Wales, during September, 1954. *D. purpurascens* was collected at Barrington Tops, New South Wales, during October, 1954. Counts of the last three species were made on material brought back to Sydney from the field. All counts were made from smear preparations of pollen mother cells stained with aceto-orscin stain.

As shown in Table 1, the chromosome number for all the Australian species counted is n = 13, which indicates that these plants are diploid species and that 13 is the basic

Table 1.

Chromosome Number in the Winteraceae.

Species.	Section.	Meiotic Chromosome Number.	Somatic Chromosome Number.	Chromosome Count by.
Drimys (n=13)				
D. insipida (R.Br.) Pilger	T	13	—	Hotchkiss, 1954.
D. lanceolata (Poir.) Baill.	T	13	—	Hotchkiss, 1954.
D. purpurascens Vickery	T	13	—	Hotchkiss, 1954.
D. stipitata Vickery	T	13	—	Hotchkiss, 1954.
D. Winteri Forst.	W	—	±76	Whitaker, 1933.



Text-fig. 1.—Meiosis, microspore mother cell, *Drimys insipida*. Camera lucida drawing of metaphase I showing 13 bivalents. ×2600.

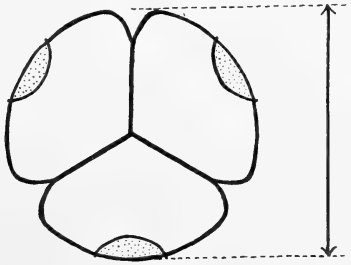
Text-fig. 2.—Mitosis, tapetal cell, *Drimys insipida*. Camera lucida drawing of metaphase showing 104 chromosomes (8 × 13). ×2600.

Text-fig. 3.—Meiosis, microspore mother cell. *Drimys purpurascens*. Camera lucida drawing of anaphase I showing 13 chromosomes. ×2600.

Text-fig. 4.—Meiosis, microspore mother cell, *Drimys stipitata*. Camera lucida drawing of a portion of anaphase II showing 13 chromosomes. ×2600.

number in this group (Pl. i, fig. 1; Text-figs. 1, 3, 4). In the material of *D. insipida* several polar views of metaphase plates in tapetal cells were encountered, one of which (Pl. i, fig. 2; Text-fig. 2) had exactly 104 chromosomes, a multiple of 13. Permanent slides have been made of material from all species except *D. lanceolata*.

The Winteraceae have long been regarded as a family of distinct significance in any account of the morphology and phylogeny of the Angiosperms. A recent paper by Bailey and Nast (1945) summarizes this viewpoint. The chromosomes have been studied previously in only one species of the family. Whitaker (1933) reported the somatic chromosome number from root tips of *Drimys winteri* to be ± 76 (4×19). He stated that, "because of the large number of chromosomes and their small size, it is difficult to make absolutely certain of the number. However, it is undoubtedly between 72 and 76, with greater likelihood of the latter figure's being correct." This conclusion seemed to be in agreement with a report by Strasburger (1905) that there were about 36 pairs of chromosomes in this species and also with the base number 19 in *Magnolia*.



Text-fig. 5.—Diagram of pollen tetrad showing the diameter measured for Table 2.

It is suggested here that the somatic chromosome number in the plants counted by Strasburger and Whitaker may have been 78, a multiple of 13. In any case, although the American species should be reinvestigated for exact chromosome number, the presence of polyploidy seems to be well established in that section of *Drimys*.

Whitaker postulated that the basic chromosome number 19, together with nodal anatomy common to *Magnolia*, *Liriodendron*, *Cercidiphyllum*, *Drimys*, *Trochodendron* and *Tetracentron*, was strong evidence for regarding this list of genera as forming a natural grouping of plants.

Subsequent workers, in intensive reinvestigations in the anatomy and morphology of these genera, have separated *Drimys* (and the Winteraceae as a whole) from immediate relationship with any of the other genera, thus leaving the Winteraceae as an isolated, relic group of general ranalian affinities (Bailey and Nast, 1945; Nast and Bailey, 1945; Swamy and Bailey, 1949; Canright, 1953). The establishment of 13 as the basic chromosome number in *Drimys* removes the putative connections founded on chromosome number between the genus and the other genera in Whitaker's list, and concurs with the findings of the recent investigators in this field.

It may be reported here also that during this study it was observed that in the four (Australian) species of *Drimys* counted, the course of development in the stamens is centrifugal. This development was noted particularly in the meiosis of the microspore mother cells. Studies to show the complete ontogeny of the stamens have not yet been undertaken. The centrifugal development of stamens when it is better understood may prove to be a specialization of considerable significance in the phylogeny of the Angiosperms and its presence in the Winteraceae is of great interest.

Bailey and Nast (1945) and Smith (1945) emphasize the separation of the Old and New World Sections of *Drimys* in both space and time, and point out that for many

TABLE 2.

Pollen Tetrad Size in the Winteraceae.

Species.	Diameter in Micra.	Measured by.	Collector.
DRIMYS.			
Section *Tasmannia*.			
D. brassii	37	I.W.B.	Brass 10126.
D. buxifolia	30	I.W.B.	Brass 4239.
D. hatamensis	35	I.W.B.	Clemens 4625.
D. hatamensis	30	I.W.B.	Kan. *et* Hat. 13935.
D. insipida	37	I.W.B.	C. T. White 6062.
D. insipida (*dipetala*)	35	I.W.B.	?
D. insipida	30	A.T.H.	Hotchkiss 98.
D. insipida	30	A.T.H.	Hotchkiss 99.
D. lanceolata	40	I.W.B.	Baker 1890.
D. lanceolata	35	I.W.B.	F. V. Muell.
D. lanceolata	30	A.T.H.	Hotchkiss 97.
D. macrantha	32	I.W.B.	Brass 4519.
D. microphylla	30	I.W.B.	Brass 12006.
D. membranacea	32	I.W.B.	F. V. Muell.
D. membranacea	42	I.W.B.	Kajewski 1291.
D. arfakensis	30	I.W.B.	Kan. *et* Hit. 13408.
D. beccariana	35	I.W.B.	Brass 11298.
D. obovata	35	I.W.B.	Brass 10570.
D. obovata	32	I.W.B.	Brass 11295.
D. oligandra	32	I.W.B.	Brass 12975.
D. piperita	32	I.W.B.	Elmer 9912.
D. piperita	30	I.W.B.	Griswold 48.
D. piperita	32	I.W.B.	Ramos 19583.
D. piperita	32	I.W.B.	Williams 754.
D. purpurascens	30	A.T.H.	Ashby.
D. rubiginosa	30	I.W.B.	Brass 12629.
D. stipitata	35	I.W.B.	Marden & Forsyth 9806.
D. stipitata	37	I.W.B.	C. T. White 7572.
D. stipitata	35	I.W.B.	?
D. stipitata	35	A.T.H.	Hotchkiss 102.
Section *Wintera*.			
D. brasiliensis var. *campestris*	45	I.W.B.	Barreto 7451.
D. brasiliensis var. *campestris*	45	I.W.B.	Barreto 7452.
D. brasiliensis var. *campestris*	47	I.W.B.	Burchell 3567.
D. brasiliensis var. *campestris*	47	I.W.B.	F.M. 1024474.
D. brasiliensis var. *campestris*	50	I.W.B.	Dusen 14504.
D. brasiliensis var. *campestris*	45	I.W.B.	Gardener 4402.
D. brasiliensis var. *campestris*	47	I.W.B.	Hassler 10586.
D. brasiliensis var. *campestris*	42	I.W.B.	Hoehne 1205.
D. brasiliensis var. *campestris*	45	I.W.B.	Hoehne 3839.
D. brasiliensis var. *campestris*	50	I.W.B.	Hoehne 28700.
D. brasiliensis var. *campestris*	45	I.W.B.	Mexia 5791.
D. brasiliensis var. *campestris*	47	I.W.B.	U.S. 1392709.
D. brasiliensis var. *retorta*	42	I.W.B.	Barreto 9083.
D. fernandiana	40	I.W.B.	Mosly.
D. granadensis var. *chiriquiensis*	42	I.W.B.	Davison 127.
D. granadensis var. *grandiflora*	45	I.W.B.	Archer 1202.
D. granadensis var. *grandiflora*	52	I.W.B.	Balls 5749.
D. granadensis var. *grandiflora*	45	I.W.B.	Cuatrecasas 6687.
D. granadensis var. *grandiflora*	50	I.W.B.	Holton 673.
D. granadensis var. *grandiflora*	50	I.W.B.	A. Joseph A106.
D. granadensis var. *grandiflora*	50	I.W.B.	Killip & Smith 17817.
D. granadensis var. *mexicana*	47	I.W.B.	Ghiesbright 518.
D. granadensis var. *mexicana*	50	I.W.B.	Hinton 1444.
D. granadensis var. *mexicana*	47	I.W.B.	Matuda 4287.
D. granadensis var. *mexicana*	45	I.W.B.	Pittier 7338.
D. granadensis var. *mexicana*	45	I.W.B.	Skutch 3585.
D. granadensis var. *mexicana*	45	I.W.B.	D. Smith 7342.
D. granadensis var. *mexicana*	47	I.W.B.	Stanley 39058.
D. granadensis var. *mexicana*	45	I.W.B.	Tonduz 12174.
D. winteri var. *andina*	47	I.W.B.	Cabera 268.

TABLE 2.—*Continued.*

Pollen Tetrad Size in the Winteraceae.—Continued.

Species.	Diameter in Micra.	Measured by.	Collector.
D. winteri var. *andina*	47	I.W.B.	Elwes 13–2–02.
D. winteri var. *andina*	45	I.W.B.	Sargent 1906.
D. winteri var. *andina*	45	I.W.B.	Wedermann 1245.
D. winteri var. *andina*	52	I.W.B.	West 4730.
D. winteri var. *andina*	50	I.W.B.	West 4900.
D. winteri var. *chilensis*	47	I.W.B.	Behn F.M. 633989.
D. winteri var. *chilensis*	45	I.W.B.	Ball.
D. winteri var. *chilensis*	47	I.W.B.	Buchtien F.M. 1024488.
D. winteri var. *chilensis*	45	—	U.S. 1177402.
D. winteri var. *chilensis*	47	I.W.B.	Gay 171.
D. winteri var. *chilensis*	42	I.W.B.	Grandjot.
D. winteri var. *chilensis*	45	I.W.B.	Hastings 355.
D. winteri var. *chilensis*	42	I.W.B.	C. Joseph 1755.
D. winteri var. *chilensis*	50	I.W.B.	Joseph 3692.
D. winteri var. *chilensis*	47	I.W.B.	Montero 173.
D. winteri var. *chilensis*	45	I.W.B.	Munoz B–117.
D. winteri var. *chilensis*	50	I.W.B.	Wedermann 73.
D. winteri var. *chilensis*	45	I.W.B.	West 5117.
D. winteri var. *punctata*	47	I.W.B.	Crooke 1897.
D. winteri	42	A.T.H.	Cult. Melbourne.
BELLIOLUM.			
B. burttianum	45	I.W.B.	Kajewski 1680.
B. crassifolium	32	I.W.B.	Schlechter 15348.
B. haplopus	42	I.W.B.	Kajewski 1994.
B. haplopus	40	I.W.B.	Kajewski 1658.
BUBBIA.			
B. archboldiana	40	I.W.B.	Brass 12712.
B. clemensiae	42	I.W.B.	Clemens 4596.
B. clemensiae	42	I.W.B.	Clemens 5157.
B. longifolia	45	I.W.B.	Brass 13868.
B. megacarpa	37	I.W.B.	Brass 10249.
B. monocarpa	35	I.W.B.	Kan. *et* Hit. 12105.
B. pachyantha	45	I.W.B.	Brass 4371.
B. semicarpoides	42	I.W.B.	C. T. White.
B. sylvestris	40	I.W.B.	Clemens 4463.
B. sylvestris	40	I.W.B.	Clemens 41142.
B. whiteana	35	I.W.B.	Brass 2278.
B. whiteana	37	I.W.B.	Kajewski 1495.
EXOSPERMUM.			
E. stipitatum	42	I.W.B.	Vieillard 2281.
PSEUDOWINTERA.			
P. axillaris var. *typica*	47	I.W.B.	Cheeseman U.S. 206642.
P. axillaris var. *typica*	42	I.W.B.	Kirk 347.
P. axillaris var. *typica*	45	I.W.B.	Travers 1908.
P. axillaris var. *colorata*	45	I.W.B.	Anderson 213.
P. axillaris var. *colorata*	47	I.W.B.	Oliver U.C. 49987.
P. axillaris var. *colorata*	50	I.W.B.	Raoul 1843.
P. axillaris var. *colorata*	42	I.W.B.	?
ZYGOGYNUM.			
Z. bailloui	47	I.W.B.	Buckholz 1213
Z. vieillardii	42	I.W.B.	Franc 1740.

reasons neither section could have been derived directly from the other. The evidence presented here lends further support to this view, but much more study, especially of other genera, is needed to clarify the cytological situation within the family. So far, cytological investigation of so few out of 88 known species in the Winteraceae represents only a beginning.

Pollen Size.

The pollen grains of the Winteraceae are shed in distinctive permanent tetrads and are different from those of other ranalian plants. In their discussion of the tetrads of pollen grains of the genus *Drimys*, Bailey and Nast (1943) state that their investigations "indicate that in general the tetrads of the Old World Section *Tasmannia* are conspicuously smaller than the tetrads of the New World Section *Wintera* of the genus". Their figures (1–5) illustrate one New World species and four Old World species of *Drimys*. Wodehouse (1935) also figures *D. winteri* Forst. (Fig. 91; Plate II, Fig. 9), and gives the dimensions of the individual grains of *D. winteri* as about 34·2μ in diameter. He also gives the dimensions of the grains of *D. piperita* Hook f. as being 18·2μ to 19·4μ in diameter. Erdtman (1943, Plate XIV, figs. 244-245) figures *Drimys axillaris* (*Pseudowintera*) and gives the tetrad dimension as 39μ. Erdtman (1952*b*) also figures the pollen tetrad of *D. winteri* (cult. Copenhagen) and gives its dimension as about 50μ. It is commonly believed, as stated by Erdtman (1952*a*), that "within a given genus the species with high chromosome number have, as a rule, larger pollen grains than those with fewer chromosomes". This, together with the occurrence of diploidy in Section *Tasmannia* contrasted with polyploidy in Section *Wintera* as reported in this paper, would lead one to look for diploidy in the remaining uninvestigated species with the smaller tetrads. It should be noted, though, that both Whitaker (1933) and Canright (1953) have investigated the relationship between pollen size and degree of polyploidy in *Magnolia*, and both have concluded that in this genus a correlation between these two factors is generally unreliable.

In Table 2 are summarized the measurements of pollen tetrads of 16 species in Section *Tasmannia*, and the four species in Section *Wintera* of the genus *Drimys*, three species of *Belliolum*, nine species of *Bubbia*, one species of *Exospermum*, one species of *Pseudowintera*, and two species of *Zygogynum*. All measurements were made of pollen tetrads mounted in lactic acid. The diameters were taken from tetrads with three grains lying in the same focal plane as indicated in Text-figure 5. In estimating the error, it should be taken into account that these are not means but measurements of tetrads which appeared to be of the common size among many on a slide. Also many of the slides had become dry and the pollen was again expanded. When fresh lactic acid is run under the cover glass, the tetrads do not expand as fully as when first mounted. Thus many of the measurements, particularly of the American material, are too low in all probability. The measurements of the Old World pollen, on the other hand, were taken from slides, many of which had never become dry, or from fresh material (of *Drimys* sp. only) which had never been dried. Nevertheless, the measurements reveal a significant difference in size of tetrads between the New World Section *Wintera* and the Old World Section *Tasmannia* of the genus *Drimys*. If the diameters of the tetrads are converted to volumes, this difference becomes even more apparent. This size difference seems to be correlated with the occurrence of polyploidy in one section of the genus and diploidy in the other. There is also a suggestion of a possible similar variation in ploidy in species of *Belliolum* and *Bubbia*.

Summary.

Chromosome counts have been made of four Australian species of *Drimys*. In each case the meiotic chromosome number was 13. Thus the Old World Section of the genus appears to be diploid, while the New World Section is polyploid.

Measurements have been made of the diameter of the pollen tetrads from 36 species of the six genera of the Winteraceae. In *Drimys* there was found to be a significant difference in size of pollen tetrads between the Old and New World Sections of the genus.

Maturation of the stamens in *Drimys* is centrifugal.

Acknowledgements.

I wish to thank Mr. J. Willis, of the Melbourne Botanical Gardens, and Dr. W. C. Ashby (University of Chicago), Fulbright Scholar at the University of Sydney (1954), for their assistance in collecting material of *Drimys*. I am also grateful to Professor

I. W. Bailey, Harvard University, who has very kindly supplied the 100 measurements of pollen tetrads of the Winteraceae as indicated in Table 2, and to my colleague, Mr. S. Smith-White, for material aid in making the chromosome counts.

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EXPLANATION OF PLATE I.

1. Meiosis, microspore mother cell, *Drimys insipida*. Photograph of metaphase I showing the same 13 bivalents drawn in Text-figure 2. ×2340.

2. Mitosis, tapetal cell, *Drimys insipida*. Photograph of metaphase showing the same 104 chromosomes drawn in Text-figure 2. ×1880.

SOME NOTES ON THE GENUS *POLYSTICHUM* IN SOUTH-EASTERN AUSTRALIA.

By Mary D. Tindale, National Herbarium, Sydney.

(Plate ii.)

[Read 27th April, 1955.]

Synopsis.

A new species of *Polystichum* Roth (Family Aspidiaceae) from New South Wales and Queensland is described. It is most closely allied to *P. formosum* Tindale. A key is provided to the four species of *Polystichum* occurring in south-eastern Australia, since three of them have been recently published as new species.

In south-eastern Australia this genus is represented by four species, viz. *P. proliferum* (R. Br.) Pr., *P. australiense* Tindale, *P. formosum* Tindale and a new species which is described below. Two other species formerly placed in *Polystichum* in several Australian floras and check lists are now referred to *Rumohra*, viz. *R. aristata* (Forst. f.) Ching and *R. adiantiformis* (Forst. f.) Ching.

The commonest Australian species is *Polystichum proliferum* (R. Br.) Pr., which is found in rain forests and in open forests on hillsides and mountains from New South Wales to Victoria and Tasmania. In New South Wales this species is mainly found south of the Barrington Tops region. To my knowledge it is the only species of *Polystichum* occurring in Tasmania, where it is very plentiful in many parts of the island. Recently I described two new species of *Polystichum* from eastern Australia in the *South Australian Naturalist*, XX, 3 (1954), 31–35, viz. *P. australiense* from New South Wales and *P. formosum* from S.E. Queensland to Victoria. Another new Australian species is described below.

Polystichum fallax Tindale, sp. nov.

Rhizoma ascendens, 2–3 cm. crassum, paleis acuminatis, papyraceis, minute denticulatis, anguste lanceolatis vel lanceolatis, 10–15 mm. longis, 2–6 mm. latis, aut opacis et castaneis, aut bicoloribus (centro nigris, nitidis, rigidis et margine aliquando castaneis), dense vestitum; paleae basis rhizomatis filiformi-acuminatae, castaneae vel brunneae, lineares, fibrillosae, integrae, 12–30 mm. longae, 0·5–2 mm. latae. *Stipes* 10–22 cm. altus, erectus, ochroleucus vel stramineus, saepe squamellis fugacibus, dense fimbriatis ornatus, paleis etiam filiformi-acuminatis, papyraceis, 3–12 mm. longis, 2–4 mm. latis, lanceolatis vel anguste ovatis, basi fimbriatis aut opacis et castaneis vel brunneis aut interdum atrobrunneis et centro aliquantum nitidis vestitus, paleae basis stipitis lineares. *Lamina* 15–42 cm. longa, 7·5–22 cm. lata, subcoriacea vel coriacea, subtripinnata vel tripinnnata, anguste elliptica, late elliptica vel anguste ovata; apice acuta vel acuminata, sine gemmis proliferis. *Rhachis* fusca vel straminea, squamellis fugacibus, dense fimbriatis ornata, paleis castaneis, membranaceis, filiformi-acuminatis, linearibus vel lanceolatis, 1·5–5·5 cm. longis, 0·2–1·5 cm. latis, versus bases fimbriatis vestita. *Pinnae infimae* 4–14 cm. longae, 1–4 cm. latae, lanceolatae vel anguste ovatae, aliquando deflexae, apice acutae vel acuminatae. *Pinnulae* oblique rhomboideae, aristatae, ca. 10–20-jugae, 7·5–20 mm. longae, 4–10 mm. latae, apice mucronatae, basi obliquae, infimis acroscopis maximis. *Sori* mediales, rotundati. *Indusium* peltatum, fugax, brunneum vel castaneum, medio saepe fuscum. *Sporae* bilaterales, globoso-ellipsoidales, perisporiis ochroleucis, cristis convolutis brunneis vestitae, 41μ–54μ × 30μ–41μ,* ala angusta, saepe dissecta, 2μ–7·5μ lata addita.

The *rhizome* erect, 2 to 3 cm. broad, densely clothed with scales which are acuminate, papery, minutely denticulate, narrow lanceolate or lanceolate, 10 to 15 mm. long, 2 to

* The spores were boiled in a 10% solution of KOH for two minutes and mounted in glycerin before measurements were taken.

6 mm. broad, either dull and chestnut, or bicolorous and then black, glossy, rigid towards the centre and sometimes chestnut at the margin; the scales of the base of the rhizome filiform-acuminate, chestnut or brown, linear, fibrillose, entire, 12 to 30 mm. long, 0·5 to 2 mm. broad. *Stipe* 10 to 22 cm. high, erect, fawn or stramineous, often bearing fugacious, densely fimbriate squamules, clothed with scales which are hair-pointed, papery, 3 to 12 mm. long, 2 to 4 mm. broad, lanceolate or narrowly ovate, fimbriate at the base, either dull and chestnut or brown, or sometimes dark brown and somewhat glossy at the centre, the scales of the base of the stipe linear. *Lamina* 15 to 42 cm. long, 7·5 to 22 cm. broad, subcoriaceous or coriaceous, subtripinnate or tripinnate, narrow elliptical, broadly elliptical or narrow ovate; the apex acute or acuminate, without proliferous buds. *Rhachis* fawn or stramineous, bearing fugacious, densely fimbriate squamules, clothed with scales which are chestnut, membranous, hair-pointed, linear or lanceolate, 1·5 to 5·5 cm. long, 0·2 to 1·5 cm. broad, densely fimbriate towards the base. *Lowest pinnae* 4 to 14 cm. long, 1 to 4 cm. broad, lanceolate or narrow ovate, sometimes deflexed, the apex acute or acuminate. *Pinnules* obliquely rhomboidal, aristate, about 10 to 20 pairs, 7·5 to 20 mm. long, 4 to 10 mm. broad, the apex mucronate, the base oblique, the lowest acroscopic pinnules the largest. *Veins* anadromous, free. *Sori* medial, orbicular. *Indusium* peltate, fugacious, brown or chestnut, often with a dark centre. *Sporangia* with long, glandless pedicels. *Spores* bilateral, globose-ellipsoidal, with fawn perispores which have brown, convoluted crests, 41μ–$54\mu \times 30\mu$–41μ, including a narrow, often broken wing 2μ–$7{\cdot}5\mu$ wide.

Distribution: South-eastern Queensland and north-eastern New South Wales.

Holotype: Moreton district, Mt. Mistake, Queensland, on slopes in open eucalypt forest with *Themeda australis*, in crevices of rocks, C. E. Hubbard No. 5196, 24.11.1930 (NSW. P6744; K.).

Queensland: Toowoomba, Hartmann, 1882 (MEL.); Mistake Range, C. T. White, 11.1920 (BRI.); head of Dalrymple Creek, Hartmann, 1875 (MEL.); Wallangarra, J. L. Boorman, 4.1914 (NSW. P1937).

New South Wales: Slopes of Mt. Kaputar, Narrabri side, 4400 ft. alt., in rock crevice, basalt, in *Eucalyptus pauciflora* open forest, P. R. Messmer, 11.9.1953 (NSW. P6741); Coryah Gap, Nandewar Range, 3900 ft. alt., frequent along running creek, on basalt mountainside in forest, L. A. S. Johnson and E. F. Constable, 6.11.1954 (NSW. P6980); Coryah Gap to Mt. Kaputar, 4500 ft. alt., Johnson and Constable, 6.11.1954 (NSW. P6981); Mt. Exmouth, Warrumbungle Mts., 2750 ft. alt., basalt, rocky gully, E. F. Constable, 26.5.1948 (NSW. P5093); near the top of the Divide between Nundle and Barry, about 4100 ft. alt., R. H. Goode No. 180, 21.11.1954 (NSW. P7022; BM.); Murrurundi, R. H. Cambage No. 1780, 10.1907 (NSW. P1934).

P. fallax has a somewhat limited range, being restricted to the northern ranges of New South Wales and the mountains of south-eastern Queensland. On the whole it occupies drier, more inland situations than either *P. australiense* or *P. formosum*.

Key to the species of Polystichum *occurring in south-eastern Australia.*

1. Proliferous buds near the apex of the lamina. Squamules absent on the stipes and rhachises.
   2. Scales at the bases of the stipes burnished and mostly with a pale border. Distal lobes of the pinnules obtuse. Pedicels of the sporangia often with 1 or 2 stalked glands. Spores with rounded protuberances ..... *P. proliferum* 1.
   2*. Scales at the bases of the stipes dull and borderless. Distal lobes of the pinnules aristate. Pedicels of the sporangia glandless. Spores with brown, broadly alate perispores ..... *P. australiense* 2.

1*. Proliferous buds absent on the lamina. Fluffy, fawn, fugacious squamules on the stipes and rhachises.
   3. Scales of the rhizome and the base of the stipes dull or glossy, markedly dimorphic, the upper scales narrow lanceolate to lanceolate, the lower numerous, linear and 1·2 to 3·0 cm. long. Spores fawn with brown convolutions and a narrow, often dissected wing ..... *P. fallax* 3.
   3*. Scales of the rhizome and the base of the stipes dull, narrow lanceolate to ovate except for a few inconspicuous, cultrate scales 4 to 8 mm. long. Spores black or dark brown, tuberculate ..... *P. formosum* 4.

Acknowledgements.

I wish to thank the directors of the National Herbarium, Melbourne, and the Botanic Museum and Herbarium, Brisbane, as well as the Rev. R. H. Goode and Mr. N. A. Wakefield for their collections of *Polystichum fallax*. My thanks are also due to Professor R. E. Holttum for looking over the Latin description of my new species, and to the staff of the National Herbarium, Sydney, for their assistance in various ways.

EXPLANATION OF PLATE II.

A specimen of *Polystichum fallax*, n. sp. Photograph by the Government Printer of New South Wales.

N.B.—In the habitat notes on the photograph, *Eucalyptus parviflora* should read *Eucalyptus pauciflora*.

THE NYMPH OF *EUSCHÖNGASTIA PERAMELES* (WOMERSLEY, 1939): ACARINA, TROMBICULIDAE.

By Robert Domrow, Queensland Institute of Medical Research, Brisbane.

(Nine Text-figures.)

[Read 30th March, 1955.]

Synopsis.

The nymph of *Euschöngastia perameles* (Wom.) is described, being the first of this genus to be correlated with its larva in Australia. The nymphs emerged 18 to 31 days after detachment, including an active period up to seven days before quiescence.

Of more than sixty known Australian species of Trombiculidae *sens. strict.*, only eleven are known as nymphs or adults. These include four nymphs or adults of which the larvae are unknown, six of which larvae and either nymph or adult are known, and one in which correlation is circumstantial. Correlation between larva, nymph, and adult is complete in only four species, but not with Australian material.

Larvae of more than 25 species of *Euschöngastia* Ewing are recorded from Australia, but very little is known of their nymphs or adults. Womersley and Heaslip (1943) recorded larvae of *E. indica* (Hirst) from Queensland, but, though its nymph and adult are well known from S.E. Asia and New Guinea, no Australian material has been bred. It is not known whether *Schöngastia westraliensis* (Wom., 1934), described from a single adult, is a true *Schöngastia* or a *Euschöngastia*.

The nymph of *Euschöngastia perameles* (Wom., 1939) is described in the present paper. The larvae are common on the bandicoot, *Isoodon obesulus*, in S.E. Queensland, their favourite site of attachment being the soft perineal skin, where they cluster in small groups, producing swollen areas about 3 mm. wide with ulcerated centres. These form thick serous scabs, in which the larvae are embedded "rosette-fashion", though not covered externally. The larvae form typical sucking tubes, which penetrate the scab and are visible in sections of ulcerated skin. The yellow, engorged larvae are easily picked out with a needle, or disengage themselves if the isolated scab is left standing overnight. Three series of larvae were set up to obtain nymphs.

Method.

All three series were placed in excavated blocks with moist soil or filter paper, and condensed droplets of water were always present on the lid. The blocks were then placed in a sealed chamber over a saturated solution of ammonium chloride, giving a relative humidity of 80%. The temperature ranges of the three series were 61 to 81°F., 64 to 82° (except for three days when the temperature dropped as low as 54°), and 61 to 88° respectively.

Four larvae (Annerley, Brisbane, 25.v.54), were set up in the first series. Next day three were quiescent, with their legs stretched upwards and forwards, while the fourth was still active. This one was transferred to a separate block with sterile soil, because fungus appeared in the original block; it became quiescent that afternoon. The other three were lost to fungus. On the eleventh day, a yellowish mass retracted from the anterior part of the nymphochrysalis, giving the legs, podosoma, and scutal region a pale, empty appearance. On the twelfth day this effect had increased, the yellow mass was smaller and more concentrated, and the body had become relatively elongate, with a faint medial constriction. On the eighteenth day a velvety, straw-coloured nymph, which darkened to yellow after four hours, was found. The larval pelt was not recovered. The nymph was quite active, and had no difficulty in walking over, or insinuating itself

between, the particles of wet soil. The front legs were waved about continually, and seemed to be used essentially as tactile organs, an observation which is supported by the large number of sensory setae on tarsus I compared with the remaining leg segments (see Table 2).

The second and third series were placed on two thicknesses of wet filter paper in individual blocks to facilitate finding the larval pelts. Five larvae (Mt. Nebo, 30.vii.54) formed the second series. Next day three were still actively walking about; the last one became quiescent on the fifth afternoon. While active, the larvae became trapped in water droplets, and, though they were always released at first, it soon became evident that the water had no effect whatever on them. The characteristic retraction of the internal tissues from the legs, etc., started on the eleventh day, and on the eighteenth day the legs of one nymph were seen inside the larval pelt. Two nymphs were found after 21 days, and two more next day. The last two were not killed for two days, but their colour did not change. The fifth larva died.

Five larvae (Annerley, 24.ix.54) were set up in the third series. The last one became quiescent after seven days, and three nymphs were found after 31 days. In the second and third series all larval pelts were recovered. Examination of these showed that the larval skin was split transversely in front of the scutum, and that a wide strip of cuticle (including scutum and eyes) had been torn back almost to the end of the hysterosoma, allowing emergence of the nymph.

EUSCHÖNGASTIA PERAMELES (Womersley, 1939).

Types: Five morphotype nymphs in collection of Queensland Institute of Medical Research, Brisbane, two at South Australian Museum, Adelaide, and one at Institute for Medical Research, Kuala Lumpur. All eight specimens reared from engorged larvae from *Isoodon obesulus*, Brisbane and Mt. Nebo, S.E. Queensland, June to September, 1954. Correlated larval pelts accompany seven of the nymphs.

Description of Nymph.

Body: Mean idiosomal length 757μ (range 720 to 780μ), breadth across propodosoma 322μ (300 to 345μ), across hysterosoma 371μ (330 to 390μ); fairly well-marked constriction at level of posterior pair of coxae; pale, velvety yellow in life. Genital area oval (Text-fig. 9), 105μ long, with two pairs of genital suckers; anterior sucker 25·3μ, posterior sucker 20·4μ long. Two narrow genital plates each with seventeen to twenty ciliated setae in two rows; two anal plates (Text-fig. 5) not so narrow, 78·8μ long, with about twelve ciliated setae.

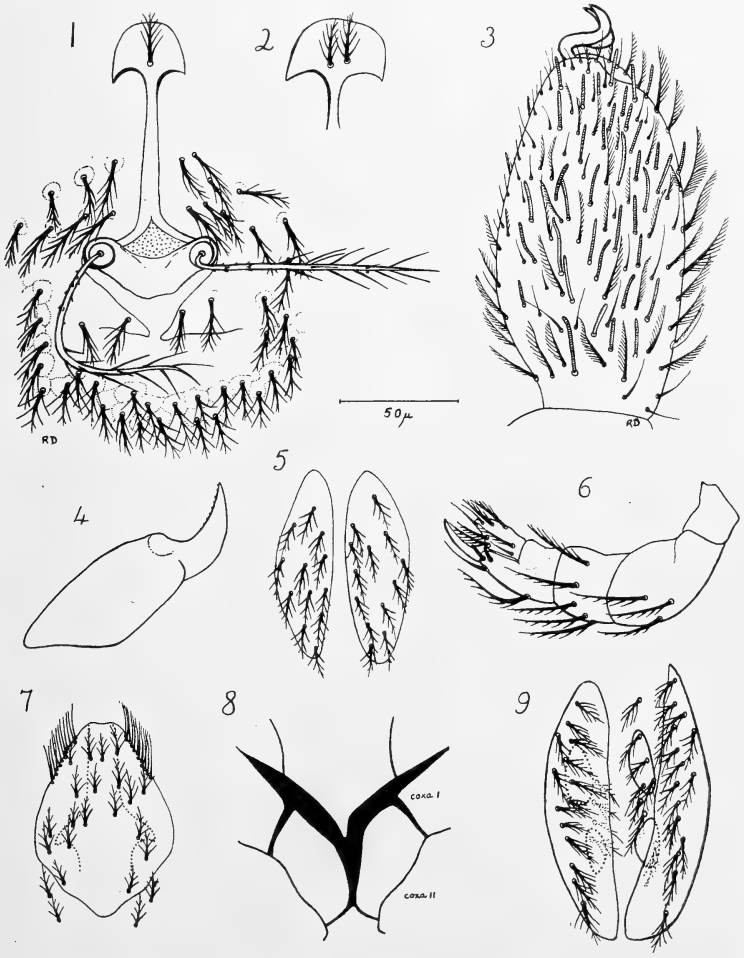
Gnathosoma: Chelicerae (Text-fig. 4) with row of fine teeth (difficult to see at some angles) on concave dorsal edge; blade 30·8μ long. Hypostome (Text-fig. 7) blunt, with two patches of about 24 simple setae laterally, behind which are about twenty scattered ciliated setae.

Palpi (Text-fig. 6) 5-segmented; tarsus 28·8μ, tibia 35·8μ, genu 31·5μ, femur 61μ long (in lateral view); tibial claw 25·9μ long. Femur with two to four ciliated setae dorsally, one shorter laterally, and one or two ventrally; genu with about four similar setae dorsally and about five ventro-laterals; tibia with about five dorso-lateral ciliated setae; in addition to strong apical spine, tibia with one thin, external and (?)two shorter internal sub-apical accessory spines; tarsus with six ciliated setae, and two apical and (?)one internal basal simple setae.

Legs: Leg I largest, leg IV longer than legs II and III, which are almost equal. Lengths excluding claws, I 531μ, II 341μ, III 319μ, IV 385μ; all 7-segmented; coxae I with precoxal plates fused medially (Text-fig. 8). All tarsi with two strong, equal claws. Coxae I & II and III & IV in two distinct groups, only coxae I being fused. Tarsus I 134μ long, 69μ high; tibia I 74μ long, tarsus II 75μ long, tibia II 44μ long (all in lateral view, after Womersley, 1952, p. 17).

Scutum (Text-fig. 1): Sensillary area roughly diamond-shaped, with anterior part punctate between sensillary bases. Tectum not dentate anteriorly; single tectal seta in all but one specimen, which has two (Text-fig. 2); there is only one AM seta in larval

pelt of this specimen. No median carina on sensillary area. Posterior apodeme with irregular sides, sometimes with two sinuous lines diverging laterally at the apex, as in *S. maldivensis* (see Womersley, 1952, plate 102A). Sensillae filiform, of fairly uniform thickness, but slightly thicker medially, with basal barbules merging into ciliations to



Text-figs. 1-9.

Euschöngastia perameles (Wom., 1939). Nymph. 1, Scutum and surrounding setae. 2, Abnormal tectum with two tectal setae. 3, Setation of tarsus I in lateral view. 4, Chelicera. 5, Anal plates. 6, Inner dorsal view of palpus. 7, Hypostome in ventral view. 8, Pre-coxal plates (setation omitted). 9, Genitalia, slightly distorted by pressure.

17μ long distally. Eyes absent. Parascutal setae one on each side, with variable number of setae laterally. The scutal standard data are given in Table 1 after the system suggested by Audy, 1953.

TABLE 1.

Standard Data (in Micra) of Scutum of E. perameles.

	CTL	ASL	SB	ASL / SB	PSL	PAD	TS	SS	SENS
	72	93	41	2·27	21	42	17	28	119
	70	83	37	2·24	17	35	19	28	112
	70	80	35	2·29	18	38	19	28	102
	73	84	37	2·27	17	38	17	28	112
	66	83	38	2·19	17	35	17	26	105
Mean	70·2	84·6	37·6	2·25	18·0	37·6	17·8	27·6	110

Setation: Body setae short, strongly ciliated, on small close-set, sub-circular platelets 10·5μ in diameter; dorsal setae 22·7 to 31·5μ, ventral setae similar, but shorter, 17·5 to 22·7μ long. The essential leg setation is set out as exactly as possible in Table 2, after Audy (1953); however, variation is considerable, especially with the normal ciliated setae. The blunt, finger-like, sensory setae are narrow, to 21μ, the simple, tapering, sensory setae to 28μ, and the normal ciliated setae to 35μ long. Micro-setae were seen only on the three segments noted. The detailed setation of tarsus I is given in Text-figure 3. Pre-coxal plates with about seven ciliated setae each.

TABLE 2.

Setation of Legs of E. perameles.

Segment.	Microsetae.	Blunt Finger-like.	Fine Tapering.	Normal Ciliated.
Tarsus I	Several v	*c.* 60 dl, few v	*c.* 30	60+
Tibia I	(1d)	10 dl., 1–2 v	8–10 dl	18
Genu I	(1d)	6 dl	6–7 dl	17–23
Femur I	—	—	1 ds	15–24
Tarsus II	—	4–6 dl	3 d	*c.* 30
Tibia II	—	2 dl	2–4 d	17–26
Genu II	—	—	2–3 d	12–18
Femur II	—	—	(1 ds)	16–23
Tarsus III	—	1 or 2 dl	—	25–35
Tibia III	—	—	2–4 d	9–24
Genu III	—	—	2–3 d	6–18
Femur III	—	—	(1 ds)	9–17
Tarsus IV	—	2 dp	2–3 d	24–32
Tibia IV	—	—	4–6 d	14–30
Genu IV	—	—	2–4 d	8–20
Femur IV	—	—	—	8–19

d, dorsal; v, ventral; l, lateral; p, proximal; s, distal.

Taxonomic Notes.

In Womersley's key (1952, p. 376), the nymph runs to caption 10, which includes *E. mutabilis* and *E. nadchatrami*. It may be separated from *mutabilis* by its longer sensillae and relatively uniform dorsal setae, from *nadchatrami* by its much shorter crista and thicker sensillae, and by the presence of pre-coxal plates. However, the relationships of the key seem to be entirely arbitrary. *E. mutabilis* is one of a group (*globulare* group of Womersley, 1952) whose larvae have strikingly approximated sensillary bases, for which Audy (1953) erected the subgenus *Helenicula*. *E. nadchatrami*

also belongs to a group of larvae with distinctive scuta, while *E. perameles* is not placed even in a tentative subgenus (Audy, 1953). Further discussion of the true relationships of this nymph is impossible until other species have been reared and correlated with their larvae.

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NITROGEN ECONOMY IN SEMI-ARID PLANT COMMUNITIES.

Part I. The Environment and General Considerations.

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Synopsis.

An introduction to the nitrogen economy of semi-arid plant communities is presented. The significance of soil nitrogen and the decline in fertility are discussed with regard to the pastoral-erosion problem. Particular attention has been paid to the mulga (*Acacia aneura*) scrub in which premature death of timber is rife. Two soils from near-virgin mallee (Eucalypt-dominated) were included for comparison.

The investigations have shown that soil organic matter is highest in the mallee; so also is soil nitrogen. In the mulga scrub the soils of the stony ridges are higher in organic matter and nitrogen than those developed on the stable dunes. Erosion is responsible for the removal of organic matter and nitrogen, since low values of both organic matter and nitrogen occur in eroded soils, scalds, and sand dunes. Most of the organic matter and nitrogen occur in the surface three inches of soil. Nitrate levels are highest in the mallee, nitrate concentration being proportional to organic content.

The C/N ratio is highest in the least eroded soils. The drop in C/N ratio with increasing erosion may be due to the loss of CO_2 following oxidation of organic matter.

Soil nitrogen limits growth in all soils when water is adequate. Phosphate levels are relatively low, though they are never limiting; the phosphate is distributed fairly evenly down the profile.

Water-soluble salts are low. In the mallee the soil solution is dominated by Ca ions, in the mulga scrub by Na ions.

Introduction.

So little work has been done on the nitrogen economy of plant communities in general, and of semi-arid communities in particular, that no satisfactory conclusions concerning the sources of fixed nitrogen to a plant community can be made. This lack of information can be ascribed partly to the concentration of work on the isolation and intensive study of a single group of organisms concerned with nitrogen-fixation, and partly to the fact that the presence of nitrogen-fixing organisms in the community suggests that these organisms are supplying the community with all the fixed nitrogen contained within the soil-plant system. Thus when legumes dominate the community or occur in abundance, it is assumed that the legumes support the community as far as fixed nitrogen is concerned; on the contrary, when legumes are rare or absent, non-symbiotic organisms are assumed to supply the nitrogen. Nitrogen fixed in other ways, for example during thunderstorms, is usually regarded as of subsidiary importance, except in special cases, such as the high rainfall areas of the tropics. Likewise, those photosynthetic organisms now known to be nitrogen-fixers have been regarded as significant contributors to the nitrogen capital of a community only in special cases, as discussed in Russell (1950).

With regard to legume-fixation, it is relevant to mention here the following two very important observations. Firstly, many legumes do not normally nodulate (Allen and Allen, 1947). Secondly, some introduced legumes in Australia produce only ineffective nodules, or do not nodulate at all because of the absence of suitable *Rhizobia* or because of unsuitable soil conditions (Vincent, 1954).

Research in western New South Wales was commenced by the writers as a result of the widespread death of the mulga, *Acacia aneura*, which formerly dominated some thousands of square miles of semi-arid country in the central portion of Australia.

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The causes of death are unknown, nor are they relevant to the present discussion. The pertinent questions at the moment are whether the mulga is contributing to the nitrogen capital of the community and, if so, what effects the widespread death of the mulga is having on the nitrogen levels in the soil.

No detailed work on nitrogen fixation has hitherto been done in this area. The only quantitative data published are figures for total nitrogen and organic carbon quoted in bulletins dealing with soil surveys for land use and irrigation projects. Since no indication of the extent of erosion or the exact nature of the herbaceous vegetation is included, these data are of little value to the present investigations. The classical work of Jensen (1940) may well be mentioned here, since this author provides reliable bacteriological data for an area adjacent to, but wetter than, the area discussed in this paper. Jensen, working on soils from the wheat belt, has shown that non-symbiotic organisms operate significantly only over limited areas, and that the actual contribution of the nitrogen-fixers to the nitrogen capital of the soil is low as far as wheat growing is concerned.

In this present series of papers an attempt will be made to account for the various sources of nitrogen to a plant community, to evaluate quantitatively the effectiveness of the various contributors, to define the significance of the death of the mulga, and to evaluate the significance (if any) of mineral nutrition in pasture degeneration and in secondary successions. This first paper deals chiefly with the general features of the environment, which are particularly relevant to the nitrogen-fixing organisms. The occurrence and activity of these will be dealt with in succeeding papers.

The Plant Communities.

Of the five common plant communities that occur in the western portion of the State, only two have been studied. Of these, the mulga scrub, *Acacia aneura* Alliance (and its degenerate and successional communities) have received by far the most attention. A few observations have been made on the mallee (*Eucalyptus oleosa–E. dumosa* Alliance) for comparative purposes. These communities have been described in detail by Beadle (1948*a*).

The mulga scrub occurs chiefly in the north-western corner of the State, and by far the greater part of it lies within the 10-inch isohyet. It is restricted to soils of light texture, on rocky ridges or on stable sand dunes. On the ridges the soils are skeletal and are derived chiefly from schists, slates, quartzites, pegmatites and sandstones. They are shallow, rarely exceeding a foot in depth, and contain abundant unweathered minerals. The deep root systems of the mulga cannot be accommodated in the soils, but the roots penetrate clefts between rocks, especially when these are tilted, as is often the case. On the stable dunes the soils are derived from calcareous or non-calcareous sands which extend to depths of up to 20 feet or more. In spite of the marked differences in soil depth and in lime content, the structure and floristic composition of the communities in the two habitats is very similar. *Acacia aneura* is dominant (local dominants of non-leguminous plants sometimes occur); other shrub species of *Acacia* and of *Cassia* are common, while annual forbs are likewise abundant.

In contrast to the mulga scrub, the mallee, which occurs in a similar climate in the south-west corner of the State on sandy soils which are usually calcareous, is dominated by non-legumes (Eucalypts); both shrub-legumes and herbaceous legumes are rare or absent.

Following the destruction of the dominant shrubs or mallees either as a result of clearing or of premature death of the mulga, the herbaceous sward increases slightly in density, but this increase is short-lived when the country is stocked. Heavy grazing has led to the degeneration of the pasture and to soil erosion. The degenerate communities (which in most cases are secondary successional stages) are usually quite different floristically from the herbaceous stratum of the original community (Beadle, 1948*a*). In extreme cases, hard scalds, pseudo-scalds (Beadle, 1948*b*) or sand dunes result. These degenerate areas are of particular significance and will be referred to in more detail below.

Climate.

Most of the area under discussion experiences a steppe climate (Köppen's classification, as modified by Lawrence, 1937); a desert climate exists in the north-west corner of the State. The salient features of the climate are summarized as follows.

The mean annual rainfall for the area is 8 to 10 inches. It is not distributed regularly or seasonally, and single falls of rain rarely exceed 2 inches. Evaporation is of the order of 60 to over 100 inches per annum; consequently the soil surface is air-dried for much of the year. Maximum shade temperatures frequently exceed 40°C. for weeks on end during the summer; temperatures below freezing are infrequent during the winter. Winds of relatively high velocity occur at any time of the year, and during the summer, when the ground is bare, they produce dust storms which remove surface soil over long distances, or sandstorms which gradually lead to the development of scalds and sand dunes.

Soil temperatures under vegetation follow closely shade air temperatures; temperatures over 40°C. are rare. Temperatures on bare soil exceed air temperatures by up to 20° C. Measurements made in bare sandy country in the Broken Hill district between 2 and 3 p.m. on a hot cloudless day in December, with the air temperature at 43°C., indicate the following approximate summer soil temperatures:

0– 5 mm.	58°C.
10–20 mm.	44°C.
At 10 cm.	38°C.
Below dark-coloured litter	58°C.
In shade of living bushes	43°C.

It is interesting that the presence of loose litter on the soil surface has little effect on reducing the temperature, which is in contrast to the effect of shade thrown by living bushes onto the soil. These figures are significant with reference to the survival of micro-organisms, and will be referred to again.

Light intensity, relevant to photosynthetic organisms, has not been studied quantitatively. Qualitative observations indicate, however, that it is only in the mallee where the soil surface is sometimes strewn with a deep layer of litter that light intensity on the soil surface may be a limiting factor for the growth of photosynthetic organisms.

Quantitative Data on Relevant Soil Properties.

The data that are included in this section have been collected in order to elucidate the nutritional status of the original soils and their truncated profiles with regard to autotrophic plants and nitrogen-fixing organisms (bacteria and certain algae). Except for the few profiles that have been studied (all from the mulga scrub) the procedure has been to sample only the top three inches of soil, irrespective of the degree of truncation of the profile. When sampling, notes on the degree of erosion and the condition of the timber have been made so that correlations between erosion or timber death and the various soil properties can be made. The techniques used are given in the appendix.

Organic Carbon.

Quantitative data for surface samples are included in Table 1. In soils where erosion is apparently not significant, the highest organic content is found in the mallee. For the mulga scrub the soils on the ranges are significantly higher in organic matter than those on the dunes. This may be due to the concentration of organic matter on the ranges into pockets among the rocks, which are commonly exposed at the surface.

Erosion in all cases causes a marked decrease in the organic content of the soil. On the ranges, where water erosion predominates, the organic matter is removed with mineral soil and possibly accumulates at lower levels. However, on the dunes, where wind erosion is the predominant or sole agent of removal, the organic matter is winnowed out of the soil during dust storms, reducing the organic matter level to very low values. Furthermore, deflated drifting sand may be blown onto other soils, thus burying the organic matter of the latter and producing pseudo-profiles, as discussed in the next section.

Distribution of Organic Matter in the Soil Profile.

Samples were collected in selected sites to determine the distribution of organic matter in the soil profile. Unfortunately, the proximity of rock to the surface in the stony ridges precludes sampling beyond a depth of about nine inches. On the stable dunes, however, sampling was continued to a depth of about two feet in three sites where the soil was not apparently eroded, though in these areas deflation with loss of organic matter could have occurred. In contrast to these three sites a pseudo-profile consisting of a surface deposit of six inches of drift sand overlying a truncated or deflated profile was investigated, as well as three scalded areas. The results are given in Table 2.

The figures illustrate the following points. In apparently non-eroded soils the organic matter is most abundant at the surface. However, the sub-surface layers also contain, in comparison with the surface, a relatively high percentage of organic matter. This probably originates from the decomposition of roots in the soil. It is of particular interest that in the sub-surface layers the percentage of organic carbon is, in all cases, about 0·2%, a point which will be referred to below.

The pseudo-profile with its accumulated surface deposit represents a very widespread condition in the west. Although soils such as these appear to be non-eroded they are virtually some of the poorest in the mulga country, since they contain the extremely low levels of organic matter typical of the dunes whence the sand has blown. It is significant that in this profile the sub-surface layers contain some 0·2% organic carbon, the figure typical of the sub-surface on non-eroded soils.

In the case of scalds the organic carbon is low throughout; the sub-surface value of about 0·2% is repeated again. The surface layers of scalds, as the figures indicate, vary considerably. The lowest value recorded is 0·08% O.C. (hard scald), the highest 0·42% (soft scald). The latter high figure is possibly accounted for by the presence of surface films of organic matter accumulated by surface wash, from dead angiospermic colonizers, or from algal growths. The low value on the other hand may be the result not of winnowing, as in the case of dunes, but rather of the respiration of micro-organisms or by oxidation of the organic matter at high temperatures. The latter has been shown to be significant in certain soils by Dehérain and Demoussy (quoted in Demelon, 1944) and by Bunt and Rovira (1954).

Soil Nitrogen.

Quantitative data for soil nitrogen are given in Table 1. Figures for total nitrogen are low in all communities, except the mallee, where the mean value of 0·3% can be regarded as high for a semi-arid soil. Since the fixed nitrogen in these soils is contained within the organic matter, it follows that with increased erosion there is a progressive fall in total nitrogen.

Available Nitrogen.—Nitrate and ammonium were estimated chemically (Table 1). In all cases ammonium is very low. Nitrate, on the other hand, in some cases is relatively high. The highest figures were obtained from the soils from the mallee, where 19·4 and 29·4 p.p.m. N (76 to >100 p.p.m. NO_3) are comparable with nitrate levels in the average wheat soil. It is of interest that some of the mallee soils in this area have been sown to wheat, and satisfactory crops have been obtained when the rainfall was adequate. The amount of nitrate is closely correlated with the organic content, from which it may be concluded that (as would be expected) the nitrate is produced in the soil through the nitrification of ammonified organic N.

Available nitrogen was also estimated in pot culture, using oats as a test plant. The figures (Table 1) correspond well with chemical data and they indicate, in addition, that for all soils investigated available nitrogen is the limiting factor when moisture conditions are adequate, except in one mallee soil. Furthermore, the amount of growth of the oats in all except the non-eroded soils is low, so low in many cases, particularly for the scalds and sand dunes, that we may well suspect that soil nitrogen rather than soil moisture may be the factor determining the rate of the secondary succession under natural conditions. Further elaboration of this point is included in the discussion.

TABLE 1.

Some Properties of Soils from the Mulga Scrub and Degenerate Communities, and from the Mallee.

For further details see Appendix.

Community ..	MULGA SCRUB.																				MALLEE.	
Habitat	Rocky Ridges.								Stable Dunes.												Stable Dunes.	
Condition of community ..	Some mulga dead.				All mulga dead.			Bare soil.	Some mulga dead.			Most mulga dead.					All mulga dead.				Near-virgin.	
Erosion	Negligible.		Slight water.		Significant water.			Severe water.	Slight wind.			Severe wind.					Completely scalded.			Secondary dune.	None.	
Sample number ..	1	2	19	22	20	21	23	24	5	40	48	4	7	41	46	49	3	6	42	44	50	31	33
Pot culture experiments* :																							
Control	118	171	297	259	223	238	203	230	213	160	178	183	87	84	84	127	50	72	81	52	33	328	253
—Nitrate ..	128	186	301	271	209	274	285	199	244	167	245	141	130	135	138	116	45	83	81	52	30	377	256
—Phosphate ..	—	389	413	591	361	258	306	346	510	194	255	287	257	230	231	224	211	425	140	142	183	386	349
Full	480	512	579	563	542	297	369	358	—	434	313	350	—	316	357	353	291	—	387	342	316	373	397
Organic carbon, %	0·81	0·85	1·09	1·30	0·64	0·64	0·61	0·48	0·68	0·45	0·60	0·38	0·28	0·26	0·29	0·33	0·15	0·14	0·25	0·004	0·08	3·1	2·4
Total N, % ..	0·083	0·116	0·098	0·175	—	0·096	—	0·066	0·093	0·060	—	0·050	0·038	—	—	—	0·024	—	0·053	—	—	0·35	0·24
C/N ratio	9·6	7·6	11·1	8·6	—	6·7	—	7·3	7·3	7·5	—	7·6	7·4	—	—	—	6·3	—	4·8	—	—	8·9	10·3
NO_3–N, p.p.m. ..	11·0	14·3	16·9	16·7	—	8·7	9·5	10·9	9·6	4·5	—	9·6	5·3	—	—	—	6·1	5·8	2·1	—	—	29·4	19·4
NH_4–N, p.p.m. ..	2·3	5·5	4·2	7·1	—	4·1	5·1	5·1	—	—	—	3·3	2·7	—	—	—	2·8	2·7	1·9	—	—	5·6	2·6
Water-soluble salts, p.p.m. :																							
Ca	10	10	20	28	16	16	11	11	26	4	10	12	18	8	7	8	33	27	4	5	8	306	114
K	21	23	13	14	10	4	10	4	6	8	11	16	5	5	17	6	4	7	9	5	3	44	14
Na	34	68	45	35	24	28	20	45	10	13	32	24	28	19	23	19	23	27	34	14	13	83	46
Total P, p.p.m. ..	230	255	413	358	318	258	308	220	255	275	275	105	135	133	130	180	90	180	204	140	125	285	237
pH	6·9	7·3	6·2	6·0	7·6	6·9	7·2	7·3	7·3	6·0	6·5	6·3	8·1	5·9	6·0	6·0	7·0	7·6	5·4	6·9	6·3	7·1	7·4

* Dry weights of plants in mg.

C/N Ratio.

The C/N ratio is not a constant for the soils investigated. On the contrary, there is a gradual drop in the ratio which is correlated with the degree of erosion. The virgin or near-virgin communities give C/N values approximating the usual value of 10. Values well below 10 are found, however, in eroded soils, the greater the erosion, the lower the ratio. Even if we assume that the carbon figures are low on the grounds that the technique used does not recover 100% organic carbon, the trend in C/N ratio will still exist. We have no conclusive explanation for this drop, but tentatively advance the following: In a system from which the supply of organic matter from leaf fall is reduced or cut off, as on eroded soils (particularly on scalds, where the annual increment is close to zero), microbial activity commences when the soil becomes moist; CO_2 is lost during respiration and the resultant organic matter becomes richer in nitrogen, and in the extreme (the condition probably never exists) the whole of the carbon and nitrogen would be contained within the microbial cells with small quantities in the form of ammonium and nitrate. Though this explanation is purely theoretical, it is supported by the observation (above) that the surface of severely eroded soils is lower in organic carbon than are the deeper layers in the same profile. More detailed investigations of this phenomenon are being carried out.

Soil Phosphorus.

Total phosphorus (Table 1) varies considerably not only from community to community, but also from site to site within the same community. For non-eroded areas the highest values were recorded from the rocky ridges, the lowest from a mulga stand on the stable dunes. The lowest of the recorded figures indicate poor phosphate levels. The figures are similar to those quoted by Jessup (1951) for soils of arid South Australia. The highest cannot be regarded as high for semi-arid soils. For comparison the lowest figures quoted by Fuller and McGeorge (1951) for certain semi-arid soils of Arizona are of the same order as the highest figures obtained for soils from western New South Wales.

Available phosphate was determined in pot culture (Table 1); the figures indicate that phosphate is never a limiting factor, though in some soils the level is low in comparison with optimum requirement as indicated by the dry weights of the full culture treatment. There appears to be a good correlation between available phosphate determined by this technique and total phosphate determined chemically.

Phosphate levels need cause no concern from the economic point of view, since the phosphate content of the soil is not closely correlated with the organic carbon, and for this reason critical losses of phosphate cannot occur through wind erosion, as

Table 2.

Distribution of Organic Carbon and Phosphorus in the Profile of Soils of the Mulga Scrub.

Habitat ..	Rocky ridges.				Stable dunes.			
Condition of profile.	Possibly some sheet erosion.				No apparent erosion.		Drift-sand accumulation of 6" over surface.	Wind eroded (scalded).
Herbaceous cover after rains.	Continuous.				Continuous.		Sparse.	None.
	O.C. %	P. p.p.m.	O.C. %	P. p.p.m.	O.C. %	P. p.p.m.	O.C. %	O.C. %
0– 1 inch ..	0·93	228	0·77	395	1·08±0·24	338	0·07	0–½ 0·21±0·13 ½–1 0·19±0·05
1– 3 inches ..	0·48	—	0·84	352	0·39±0	—	0·09	0·16±0·05
3– 6 ,, ..	0·45	210	0·23	285	0·33±0·14	205	0·12	0·18±0·05
6– 9 ,, ..	0·48	228	—	—	0·28±0·07	228	0·25	0·17
9–12 ,, ..	—	—	—	—	0·22±0·11	200	0·29	0·15
12–20 ,, ..	—	—	—	—	0·21	190	0·18	—

is the case with nitrogen. On the contrary, phosphate is associated with the mineral fractions of the soil and, although significant concentrations occur in the organic matter, it is still fairly evenly distributed down the profile (Table 2).

Water-Soluble Salts.

Water-soluble salts (Table 1) are by far the highest in the mallee, where the soil solution is dominated by calcium ions. In all other communities sodium is the dominant ion. In all cases the supply of calcium and potassium would appear to be adequate for plant growth, and in all cases the concentration of the sodium ion is low, so that no inhibition either of the growth of green plants or of micro-organisms would be expected.

Discussion.

The results which have been presented above enable us to draw a few simple conclusions; they also indicate how little is known about the fundamental processes concerned in the nitrogen economy of plant communities and the basic causes of degeneration and regeneration of plant communities. It is now clear that a simple solution to the mulga death problem and its many ramifications cannot be expected. Indeed a vast amount of research has still to be done in the fields of soil chemistry, microbiology, and plant physiology before the ecological aspects can be handled properly. In a short paper presented to the International Botanical Congress (Beadle and Tchan, 1954) a brief résumé of the overall problem has been given. With the additional data that have been presented above, some advances in the discussion can be made.

The figures for organic carbon and total nitrogen for soils affected variously by erosion leave no doubt that most of the organic matter and nitrogen are lost through erosion. Other sources of loss, however, cannot be overlooked. Loss of carbon must inevitably result from the respiration of micro-organisms (and possibly by chemical oxidation) in areas where additions of organic matter from plant debris are reduced to very low levels, as on badly eroded country. That this is occurring is suggested by the low levels of organic carbon in the surfaces of eroded areas, and by the fall in C/N ratio in such areas. Further investigations of these losses both under field and laboratory conditions are in progress.

The significance of such losses in communities where nitrogen is the limiting mineral nutrient cannot be over-emphasized. The significance of loss of nitrogen needs no further comment, but an additional remark on the organic matter is relevant. Since non-symbiotic organisms are entirely dependent on soil organic matter for their supply of energy, any loss in organic content must reduce the activity of non-symbiotic nitrogen-fixing organisms.

A further consequence of reduced levels of soil nitrogen is the possible change in floristic composition of the herbaceous sward. Formerly secondary successions were thought to be controlled either by micro-climatic conditions or by soil moisture. Now, however, we must consider an additional factor, soil nitrogen. It may well be that soil nitrogen is controlling both the rate of the succession and the species composition at the various stages in the succession, at least in some localities. If this be the case, then species of the successional stages would have low nitrogen requirements and low protein-content, which is of considerable significance to the pastoral industry.

A note on the possible sources of nitrogen to the communities may be inserted here. The known biological sources of nitrogen to a soil are those supplied either through the symbiotic *Rhizobia* associated with legumes or from non-symbiotic bacteria and photosynthetic organisms. A small contribution could also be expected from rainfall, and since rainfall is about equal for all communities, this addition should be the same for all communities. The figures for total nitrogen quoted in Table 1 show that the highest nitrogen figures occur in the mallee where legumes are extremely rare or lacking, and from this the tentative conclusion may be drawn that *Rhizobia* possibly play only a sub-dominant or even inconsequential role in the nitrogen economy of the legume-dominated communities. Apart from this observation, no conclusions as to the

sources of nitrogen to the community can be made at this stage in the work. Many of the hypotheses and tentative conclusions outlined above are still under investigation by the writers. The second paper in this series will deal with the non-symbiotic nitrogen-fixing organisms.

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APPENDIX.

Techniques.

(*a*) *Field Sampling.*

About 1·5 kg. of the surface three inches of soil (excluding surface litter) from eight closely spaced areas were collected and mixed. In the case of profiles only a single pit was sampled, at depths indicated in the tables.

(*b*) *Pot Culture Experiment* (in glasshouse, Sydney).

Four plastic pots of soil (1 kg. in each pot) of each of the samples were treated as follows: (i) full culture solution added; (ii) full culture solution minus phosphate was added; (iii) full culture solution minus nitrate was added; (iv) distilled water only added. The full culture solution consisted of 10 c.c. M.KNO_3, 4 c.c. M.KH_2PO_4, 2 c.c. of M.$MgSO_4$ and M.$CaCl_2$ per pot. Oat grains were sown on the soil surface and covered with washed sand. When the oat seedlings had become established all but four were removed from each pot. The pots were watered when necessary. After a period of six weeks (mean temperature 30 $\pm$ 5° C.) the tops of the plants were harvested, dried at 100° C. and weighed. The mean weight of the plants in each pot was calculated. This mean weight is taken as a measure of the relative nutrient levels under the four treatments.

(*c*) *Organic Carbon.*

Organic carbon was measured by the Walkley-Black method, as outlined by Piper (1944). The results are given as carbon, and no correction has been made to account for incomplete recovery of the organic matter.

(*d*) *Total Nitrogen.*

Total nitrogen was estimated by the Kjeldahl technique. Ten to twenty gm. of soil were used, the estimates being made in duplicate. After reduction of nitrate with zinc powder (Jensen, 1940) the soil was digested. A drop of mercury was added in addition to $CuSO_4$ and K_2SO_4. After the dark colour had disappeared gentle heat was maintained for three hours. The mixture was cooled and the liquid made up to 500 c.c. Samples of 50 c.c. of this liquid were distilled with hyposulphite. The ammonia was titrated with N/56 H_2SO_4.

(*e*) *Ammonium.*

Ten gm. of soil were extracted with 60 c.c. N.NaCl, and 30 c.c. of the filtered extract were distilled with MgO. The ammonia was collected in water and measured quantitatively by the addition of Nessler's reagent. Measurements were done on a Unicam spectrophotometer at λ 4300Å.

(*f*) Nitrate.

Ten gm. of soil were extracted with 60 c.c. of water and the colloidal suspension was flocculated with a mixture of magnesium and calcium carbonates. Nitrate was estimated in the filtered solutions using the phenyl disulphonic acid technique of Lees and Quastel (1946). A Unicam spectrophotometer was used, measurements being made at λ 4250Å.

(*g*) *Total Phosphate.*

Five gm. of soil were boiled for four hours with 25 c.c. conc. HCl on a sandbath. The solution was filtered and made up to 250 c.c. Two c.c. of this solution were pipetted into a 50 c.c. volumetric flask and diluted with water. The solution was made slightly alkaline with N.NaOH, using p-dinitrophenol as indicator. The excess alkali was neutralized with N/10 H_2SO_4. Water was added to make about 45 c.c. One c.c. of 2·5% ammonium molybdate and 0·5 c.c. of freshly prepared $SnCl_2$ were added and the volume was made up to 50 c.c. with distilled water. The intensity of the blue coloration was measured at λ 6750Å on a Unicam spectrophotometer.

(*h*) *pH.*

pH was measured at the sticky points of the soils on a glass electrode potentiometer.

(*i*) *Water-soluble Salts.*

Twenty gm. of soil were extracted with 60% alcohol. The solution was filtered and Ca, K and Na were estimated after suitable dilutions on an Eel flame photometer. Blank estimations were done on the alcohol at the appropriate dilution.

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STUDIES OF BEAN ANTHRACNOSE IN AUSTRALIA.

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(Plate iii.)

[Read 27th April, 1955.]

Synopsis.

Two sets of studies of the host-parasite relationships shown between *Colletotrichum lindemuthianum* (Sacc. and Magn.) Briosi and Cav. and bean varieties were made. In the first, carried out between the years 1925 and 1928, 12 isolates of the fungus showed that 11 were similar to the U.S.A. beta race, and the remaining one has been designated Aust. *A*.

In the second set of studies, made between 1944 and 1952, 14 isolates studied on the same basis yielded seven races, all different from the two previously determined. Using a different selection of better known bean varieties, they have been sorted into eight races designated Aust. 1 to Aust. 8.

Making use of more than 130 bean varieties, the 14 isolates can be separated into 42 different groupings on the basis of the reactions shown to inoculation: the majority (98) of varieties were resistant to all the isolates.

From the varieties having both rust and anthracnose resistance, parents were chosen (Westralia receiving particular attention) for crossing with susceptible dwarf varieties, in order to incorporate in them the needed resistance. Serious incompatibility problems were encountered.

Introduction.

The disease known as anthracnose of beans, caused by the fungus *Colletotrichum lindemuthianum* (Sacc. & Magn.) Briosi & Cav., was first satisfactorily recorded overseas in 1843, and has been known in New South Wales since 1894 (Noble et al., 1934). In bean-growing countries it is an important disease causing serious crop losses under favourable weather conditions. An extensive bibliography is given by Harter and Zaumeyer (1944) as well as by others.

The studies here reported were commenced in 1925, but only in more recent years have they been intensively carried forward.

Materials and Methods.

In 1921 a set of bean varieties then in use as differentials in sorting out physiologic races of the fungus was brought from Cornell University, U.S.A.; their reactions to the alpha, beta and gamma races were supplied by Dr. L. M. Massey. The original varietal names have been retained, and the beans have since been maintained as single plant—often single pod—selections, with the exception of three which were lost in adverse seasons. Recently many other varieties have been obtained from various sources, thanks to generous responses to requests for material; stocks of them have been maintained in the same way.

Seedlings have been used in plant house tests; in only a few cases has it been possible to check the results on mature plants. Seed treated with spergon was sown in four-inch pots of steamed soil which were kept on plant house benches. After emergence of the true foliage leaves the plants were atomized with a suspension of the inoculum under test, and the pots placed in an incubation chamber for a period of 36 to 48 hours, depending upon the prevailing weather conditions. Since there is the well-known inhibition of disease development at temperatures above the critical point, the work was done at the necessary lower temperature levels. The incubated plants were allowed to develop in the plant house, and when the lesions were clearly developed on the susceptible members in a series (usually after 7–10 days), notes were taken on the whole batch. In some instances where seed was in short supply, the resistant plants were pruned after note-taking, and if after the lapse of a proper period no lesions were showing on the new growth, they were used for the succeeding inoculation.

The inoculum came from various sources. The diseased material was plated in the usual way and pure cultures of the organism obtained; single spore cultures were used in several of the experiments, but this was not general. Individual cultures were maintained on potato-dextrose-agar. Inoculum for use in the plant house was obtained from the abundant fruiting growth made from transfers to sterile bean pods. It was agitated in tubes of sterile water for atomizing on to the plants. Particular series of pots under test were kept in isolated positions in the plant houses. There were cases where unexpected high temperatures made it necessary to repeat the experiment under favourable conditions. In all cases where any doubt existed the work was repeated.

Note-taking presented difficulty. In the case of fully susceptible varieties the seedlings were soon killed, whilst at the other end of the scale there was full immunity to attack. All kinds of intergrading reactions were found. It was finally decided to adopt a notation in which

0 = Immunity: hardly any visible reaction to inoculation.
1 = Resistance: small scattered lesions; plants recovered.
2 = Resistance: lesions obvious but no fructifications; plants recovered.
3 = Susceptible: numerous lesions and severe killing of tissues with abundant development of fructifications; plants died later.
4 = Susceptible: plants wilted and quickly died.

To denote variations in these behaviours, plus and minus signs were sometimes used. Because of the marked effects of changes in the environmental conditions, it is considered that the broad classification into resistant and susceptible classes is all that is desirable. With the variations that occurred in plant house conditions, reaction changes were found within both the resistant and the susceptible classes, but reasonable assurance was felt in regard to the determination that has been set down for one or other of the two classes.

Experimental Results.

Studies of the Pathogen.

Isolates from different sources and at different times showed differences in their behaviour when grown on potato-dextrose-agar under the same conditions. The growth was usually dark and closely appressed to the surface, where the production of acervuli varied greatly. Others gave a somewhat effuse aerial development, with variations in its colour. Sectoring in some cultures was noted.

Clear differences of this sort led to attempts being made to produce the perfect stage of the fungus from combinations of isolates growing on differing substrates under varying conditions.

There were instances in which growth aggregations resembling perithecia developed, but in no case were asci found. This is in accord with other workers' results.

Specialization.

The occurrence of variations in the susceptibility of beans to the disease was reported by Barrus in 1911, and since then many others have demonstrated the presence of physiologic races of the organism. The determinations have been based upon results obtained by using sets of bean varieties which have not always been uniform. Satisfactory comparisons of the results thus become difficult, if not impossible. It has been customary, however, to try to relate the results to those initially reported by Barrus (1918) and Burkholder (1923), who described three races, which they named the alpha, beta, and gamma races.

The work herein reported is conveniently considered as two sets of studies. The first, carried out between the years 1925 and 1928, involved the use of U.S.A. varieties which included differentials used by Barrus and Burkholder, with the addition of two common commercial varieties in use in New South Wales.

Then came a gap during which anthracnose work could not be carried out. The second set of studies covers the period 1944–1952, when work on a more extensive scale was done.

First Set of Studies.

At intervals during 1925 to 1928 diseased beans were obtained from various sources. In a number of cases they came from vegetable markets, and therefore their origin could not be determined. Pure cultures were made and used in the production of inoculum. In all, 12 distinct isolates were obtained.

In the tests it was found that 11 of them behaved similarly, but that the other one was differentiated clearly on one variety. The results are set out in Table 1, in which the reactions reported for the alpha, beta, and gamma races are included for purposes of comparison: cultures of them were not available for side-by-side tests.

TABLE 1.

Reactions Given by Isolates of C. lindemuthianum *on Bean Varieties Compared with those Recorded for U.S.A. Races.*

Accession Number.	Variety.	Reactions of Races.				
		Alpha.	Beta.	Gamma.	11 Isolates (Beta).	1 Isolate Aust. *A*.
B1	Red Cranberry (Low's Champion).	S	S	S	S	S
B2	Large White Marrow.	R	S	S	S	S
B3	Black Valentine.	S	S	S	S	S
B4	Tennessee Green Pod.	S	R	R	R	R
B5	Lazy Wife.	S	S	S	S	S
B6	Wardwell Kidney Wax.	S	S	S	S	S
B7	Red Kidney.	R	S	S	S	S
B8	Kentucky Wonder.	S	R	R	R	R
B9	Scotia.	S	R	R	R	R
B10	Well's Red Kidney.	R	R	S	R	R
B11	Eureka.	S	S	S	S	S
B12	Michigan Robust.	S	R	R	R	R
B13	White Imperial.	R	R	S	R	R
B14	Yellow Eye (Improved).	R	S	S	S	R
B15	Canadian Wonder.	S	S	S	S	S
B16	Epicure.	—	—	—	R	R

The original distinction between the alpha and beta races was made on the reactions shown by many varieties. Amongst them, B4 Tennessee Green Pod, B8 Kentucky Wonder, and B9 Scotia were susceptible to the alpha but resistant to the beta races, whilst B2 White Marrow, B7 Red Kidney, and B14 Yellow Eye were resistant to the alpha but susceptible to the beta races (Barrus, 1918). The gamma race differed from them in that B10 Well's Red Kidney and B13 White Imperial, which were resistant to the alpha and beta races, were found to be susceptible to the gamma race (Burkholder, 1923).

From Table 1 it is seen that the two groups of isolates differ in their behaviour on the variety B14 Yellow Eye (Improved), which also differentiates the alpha on the one hand from the beta and gamma races on the other. One of the two races (of which there were 11 isolates) agrees with the beta race. The other is different, and is here styled Aust. *A*. Both races show the same behaviour on the two N.S.W. varieties, B15 Canadian Wonder and B16 Epicure.

Second Set of Studies.

In this work the same U.S.A. varieties were used as differentials, but a different series of isolates was involved and, in addition, numerous other varieties were tested for their reactions.

The isolates were obtained from diseased material collected by the late Mr. R. D. Wilson, with the exception of No. 1034, which was submitted by Miss D. E. Shaw, and of No. 1026, by Mr. D. W. Reilly; to these thanks are tendered. A culture of the organism sent from New Zealand in 1944 was used in comparison with the others.

Details of the isolates are given in Table 2.

The varieties used included most of those already listed in the first set of studies, but many others also came up for test. The Principal of the Hawkesbury Agricultural College, Mr. E. A. Southee, Mr. Shirlow of the N.S.W. Department of Agriculture, and Mr. P. I. Pryke of the Victorian Department of Agriculture, were particularly helpful in supplying seed, and grateful thanks are tendered to them.

Serious problems connected with the purity of host material soon became apparent. Numerous cases were found in which there was clearly admixture of seed in a particular sample submitted; or seed carrying the same name but coming from two different sources was found to be quite different in colour and/or shape; or apparently similar

TABLE 2.

Details of the Isolates of C. lindemuthianum *Used in the Determinations.*

Accession Number.	Date of Receipt.	Source.
767	10 : 1944	Wamberal, N.S.W.
768	do.	do.
985	7 : 1949	Sandy Creek, Queensland.
986	do.	North Coast, N.S.W.
987	do.	Moruya, N.S.W.
988	do.	Sydney Markets.
989	do.	Bodalla, N.S.W.
990	do.	Lindfield, N.S.W.
1026	3 : 1950	Auburn, N.S.W.
1028	do.	Tenterfield, N.S.W.
1034	do.	Sydney Markets.
1035	7 : 1950	Gosford, N.S.W.
1036	do.	Tenterfield, N.S.W.
1038	10 : 1950	Gosford, N.S.W.
1043	do.	Gosford District, N.S.W.

seed carrying the same name was found to produce quite different types of plant; or seed of a particular variety was found to be heterozygous for its reactions to inoculation. Pedigree work thus became necessary. Even so, it is doubtful whether the results given by a variety bearing a particular name are always comparable with those reported for the "same" variety elsewhere. Strict standardization and retention of genetic purity are essential in work of this nature.

In addition to the varieties listed and classified later, many others came up for tests in which limitations of time and of seed available made it impossible for all the tests to be completed; incomplete results of this sort have not been included.

Specialization.

Each of the isolates was used for race determination on the set of differentials listed on p. 73 under similar conditions to those used in the first set of studies.

The results are set out in Table 3, in which the determinations given on p. 73 are also included. Gaps occur where seed was not available for the tests.

From the isolates, neither the beta race nor the Aust. *A* race was obtained. The New Zealand culture corresponded with the gamma race. The 14 isolates examined were different from these all, and fall into races which are here designated Aust. *B* to Aust. *H*.

The isolates fall into the following categories:

Race Aust. *B* = Isolate 768
Aust. *C* = 767, 1038
Aust. *D* = 985
Aust. *E* = 986, 988
Aust. *F* = 987, 1028, 1036
Aust. *G* = 989, 990, 1026, 1034, 1043
Aust. *H* = 1035

An examination of the geographical distribution of the races gives little information. For example, the two collections from Tenterfield are similar, whilst the two from Wamberal are unlike. The one from southern Queensland is dissimilar to the one from the North Coast of New South Wales.

TABLE 3.

Reactions of Isolates of C. lindemuthianum *on Bean Varieties as well as the Reactions Previously Reported.*

Varietal Accession Number.	Reactions of Races.											
	Alpha.	Beta.	Gamma.	N.Z.	Aust. *A.*	Aust. *B.*	Aust. *C.*	Aust. *D.*	Aust. *E.*	Aust. *F.*	Aust. *G.*	Aust. *H.*
B1	S	S	S	S	S	S	S	S	R	S	S	R
B2	R	S	S	S	S	R	R	R	R	R	R	R
B3	S	S	S	S	S	S	R	S	S	S	S	S
B4	S	R	R	R	R	R	R	R	R	R	R	R
B5	S	S	S	S	S							
B6	S	S	S	S	S							
B7	R	S	S	S	S	S	S	S	S	S	S	S
B8	S	R	R	R	R	R	R	R	R	R	R	R
B9	S	R	R	R	R	S	R	R	R	R	R	R
B10	R	R	S	S	R	S	R	S	R	R	R	R
B11	S	S	S	S	S							
B12	S	R	R	R	R	R	R	R	R	R	R	R
B13	R	R	S	S	R	R	R	R	R	R	R	R
B14	R	S	S	S	R	S	R	S	R	S	R	S
B15	S	S	S	S	S	S	S	S	S	S	S	S
B16				R	R	R	R	R	R	R	R	R

A study of their distribution in time is also of little value. From the Gosford area three races were found in a particular year, whereas some stability is shown in other instances.

For this information a much more extensive survey of the physiologic races in regard to both time and space would be necessary.

TABLE 4.

The Identity of the Races under Consideration Shown in Simplified Form.

Race Designation.	Reactions Shown on Differential Varieties.					
	B1.	B2.	B3.	B9.	B10.	B14.
Alpha	S	R	S	S	R	R
Beta	S	S	S	R	R	S
Gamma	S	S	S	R	S	S
Aust. *A*	S	S	S	R	R	R
Aust. *B*	S	R	S	S	S	S
Aust. *C*	S	R	R	R	R	R
Aust. *D*	S	R	S	R	S	S
Aust. *E*	R	R	S	R	R	R
Aust. *F*	S	R	S	R	R	S
Aust. *G*	S	R	S	R	R	R
Aust. *H*	R	R	S	R	R	S

It will be seen in Table 3 that a number of the varieties do not serve to differentiate the Aust. races, showing either susceptibility or resistance throughout the tests. Thus B7 and B15 are susceptible, and B4, B8, B12, B13, and B16 are resistant throughout. This makes it possible to simplify the race determinations as shown in Table 4, in which the comparable alpha, beta, and gamma results are included. The race designated Aust. *A* in the first set of studies is also set down.

Tests of Varietal Behaviour to Attack.

Using 14 of the same set of isolates, numerous varieties of beans were subjected to test. One of the original isolates (Acc. No. 768) was lost before the tests had been completed.

An extreme range of diversity to attack was shown. The varieties fell into one or other of 42 classes. At one end of the scale the class of varieties showed resistance to all

TABLE 5.

The Classes (or Races) Determined when 132 Varieties were Tested with 14 Isolates of C. lindemuthianum.

Acc. No.	Variety.	Reactions Shown.													
		767	985	986	987	988	989	990	1026	1028	1034	1035	1036	1038	1043
V2	Russia.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
V3	Roger's Stringless Green Pod Refugee.	R	R	R	R	R	R	R	R	R	R	S	S	S	R
V10	Stringless Green Pod Refugee.	S	S	R	S	S	S	S	S	S	S	S	S	S	S
V11	Pencil Pod Black Wax.	R	S	S	R	S	S	S	S	R	R	S	S	S	S
V12	Florida Belle.	S	S	R	S	S	R	S	S	R	S	S	R	S	S
V14	Blue Lake Hybrid 65.	R	R	R	R	S	S	S	R	R	R	R	R	R	R
V20	Brown Beauty (A.T.P.).	S	R	R	R	R	R	R	R	R	R	R	R	S	S
V25	Doppelite.	R	R	R	S	S	S	S	S	S	R	R	R	R	R
V28	Early Pale Dun.	S	S	S	S	S	S	S	S	S	S	S	S	S	S
V32	Tweed Wonder.	R	R	R	R	R	R	R	R	R	R	R	R	S	S
V46	U.S. Refugee No. 5	R	S	S	R	S	R	R	R	R	R	R	R	S	S
V52	Staley's Surprise.	S	S	R	R	S	R	R	S	S	R	S	R	R	S
V65	Top Crop.	R	S	S	R	R	R	S	R	R	S	S	S	S	S
V67	Unrivalled Wax.	R	R	S	R	S	S	S	S	S	R	S	S	S	S
V68	H49.	S	S	R	R	R	R	R	S	R	R	R	R	S	S
S9	Idaho H7696.	R	R	R	R	R	R	R	R	R	R	R	R	R	S
S10	Standard Pink.	R	R	R	R	R	S	S	S	R	R	R	R	S	R
S48	Red Kidney H6454	R	R	R	R	S	R	R	R	R	R	R	R	S	S
S51	Pearl Sugar.	R	S	S	S	S	S	S	S	S	S	S	S	S	S
S70	The Wonder.	S	R	R	R	S	S	R	S	S	S	S	S	S	S
S90	Florida Belle (Asgrow's).	S	R	R	R	R	R	R	R	S	S	S	S	S	S
B1	Red Cranberry (Low's Champion).	S	S	R	S	R	S	S	S	S	S	R	S	S	S
B3	Black Valentine.	R	S	S	S	S	S	S	S	S	S	S	S	R	S
B10	Well's Red Kidney.	R	S	R	R	R	R	R	R	R	R	R	R	R	R
B14	Yellow Eye (Improved).	R	S	R	S	R	R	R	R	S	R	S	S	R	R
B30	Kentucky Wonder.	R	R	R	S	R	R	R	R	R	R	R	R	R	R
B32	Wellington Wonder.	S	S	R	R	R	R	R	R	R	R	R	R	S	S
B38	Prolific.	R	R	R	R	S	S	R	S	S	R	R	R	R	R
B40	Pacer.	R	S	R	R	S	S	S	R	S	S	S	S	S	S
B41	Burbank.	R	R	R	R	R	R	S	R	S	S	R	R	R	R
B43	Yellow Eye.	R	S	R	S	R	R	S	R	R	S	S	R	R	R
B45	Norwegian.	S	S	S	S	S	S	S	S	S	S	R	R	S	S
B46	Habilla.	R	S	S	R	R	R	R	R	R	R	R	R	S	R
B54	Poroto enana.	R	R	S	S	S	S	S	S	S	S	R	S	R	R
B55	Poroto C.P.I. 11443.	R	S	R	R	S	S	R	S	R	S	S	S	S	S
B60	Supergreen.	R	S	R	S	R	S	R	S	R	R	R	R	R	R
B63	Native Bean H7789.	R	R	S	S	S	S	R	S	S	S	S	R	R	R
B67	Florida Belle.	R	S	R	S	R	R	R	R	R	S	R	R	S	S
B73	Scott's Bluff Pinto.	R	S	S	S	S	R	S	S	S	S	S	R	R	R
B74	Startler Wax.	R	S	S	R	R	S	S	S	S	S	R	S	R	S
B78	The Wonder.	R	S	S	S	R	R	S	R	R	S	R	R	S	S
B81	Standard Pink.	R	R	R	S	S	S	R	R	R	S	R	R	R	R

the isolates; at the other, susceptibility to all was shown. In between these two classes were those in which 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, or 13 of the isolates gave rise to susceptible reactions. In each of these cases resistance was, of course, shown to the remaining isolates. Furthermore, there were various groupings within these classes. For example, there were six different groupings within the "3 susceptible" class, five groupings in each of the "4 susceptible", "5 susceptible", and "10 susceptible" classes, four groupings in the "9 susceptible" class, and so on. It is clear that when large numbers of host plants are used as differentials, an extreme range of diversity is exhibited. In this case no one of the 14 isolates examined was the same when subjected to this test.

TABLE 6.

List of Varieties Tested where More than One Fell within the Several Classes.

Class 1.—*Resistant to All the Isolates.*

V2 Russia, V4 Rainy River, V5 Klein Weisse, V6 Pink, V9 Great Northern, V13 Blue Lake, V15 Blue Lake Stringless Pole, V16 Boston Marrow, V18 Burbank, V21 Californian Small White, V22 Cannellini, V23 Case Knife, V24 Case Knife Climbing White Dutch, V26 Hamburger Market, V27 Early White, V29 Emperor William, V31 Frigole Nigros, V34 Java, V35 Michigan Robust, V36 Michelite, V37 Robust, V38 Norida, V40 Navy, Canadian Type, V41 Navy, Ottawa, V42 Northern Star, V44 Purple Pod, V49 Red Mexican U. I. 3, V50 Red Mexican U. I. 34, V53 Zucker Perl, V58 Red Valentine, V61 Roumanian White Pea, V63 Pilot, V64 Bill, V69 Corbett's Refugee, S4 Otenashi, S8 Little Navy, S31 Pinto H6781, S34 Michelite, S36 B2675, S47 Pilot, S57 Small White, S66 Shravni Ghendi, S67 Native Bean H7790, S69 Fullgreen, S71 Cromer, S100 Dwarf Haricot (Comptesse di Chambord), S118 Pilot, S122 Rice, S124 Roger's Refugee 1071, B4 Tennessee Green Pod, B8 Kentucky Wonder, B9 Scotia, B12 Michigan Robust, B13 White Imperial, B16 Epicure, B18 Wiggin's Prolific, B25 U.S. No. 3, B27 Harter's 643, B28 Harter's 650, B29 Harter's 765, B31 Harter's 814, B33 Blue Navy, B35 Cecic's Epicure, B37 Kentucky Wonder, W.A., B44 C.P.I. 11272, B48 Alabama No. 1, B49 Feijao, B51 Poroto C.P.I. 11439, B52 Poroto C.P.I. 11440, B53 Poroto topero, B57 Poroto criollo, B58 Poroto cuarenton, B59 Poroto arroz chilero, B61 Ideal Market, B68 Long White Marrow, B69 St. Fiacre, B70 Resistant Kentucky Wonder, W.A., B75 Roger's Refugee 1071, B76 Medal, B77 Great Northern, B79 Fullgreen No. 1, B80 Fullgreen No. 2, B82 Roumanian White, B83 Early Pink, B84 Russia, B85 Pilot, B88 Westralia, Scarlet Runner, also ten of the original selections from which Westralia was isolated, *Dolichos Lablab* (six isolates), two of them giving "2" reactions.

Class 2.—*Susceptible to All the Isolates.*

V17 Burpee's Dwarf Stringless Green Pod, V28 Early Pale Dun, V54 Surecrop Wax U.S.A., V60 Low's Champion, S53 Granda, S85 Dwarf Pencil Pod Wax, S95 Pencil Pod Wax (Ferry Morse), B7 Red Kidney, B19 Hawkesbury Wonder, B20 Wardwell Kidney Wax, B21 Lazy Wife, B22 Stringless Black Valentine, B24 Clarendon Wonder, B26 Harter's 181 (Bountiful), B34 Stringless Green Pod French Bean, B36 (Clarendon Wonder × Wellington Wonder), B47 Frijol pico de oro, B50 Frijol guarzo rayado, B56 Feijao rayado, B64 Granda, B65 Tendergreen, B71 Staley's Surprise, B72 Red Valentine.

Class 3.

Isolates.

767	985	986	987	988	989	990	1026	1028	1034	1035	1036	1038	1043
R	R	R	S	R	R	R	R	R	R	R	R	R	R

V33 Hidatsa Red, B30 Harter's 780.

Class 4.

R	R	R	R	R	R	R	R	R	R	R	R	S	S

V32 Tweed Wonder, V39 Negro Long Pod, V45 Idaho Refugee, V56 The Wonder, V62 Medal, S17 The Prince, S59 Tweed Wonder.

Class 5.

R	S	S	S	S	S	S	S	S	S	S	S	R	S

B3 Black Valentine, B66 Black Valentine.

The various classes determined are shown in Table 5, where one variety of each is listed.

It will be noted that the variety "Florida Belle" appears in three and "Standard Pink" in two of the categories. In each case the seed came from different sources, but the variety appeared to be the same. Differences in resistance within a given variety are clearly shown.

Where more than one variety fell within a class they are set out in Table 6.

TABLE 7.

Reactions Shown by Nine Bean Varieties when Inoculated with Fourteen Different Isolates of C. lindemuthianum.

Accession Numbers of Isolates.	Race Designation.	Reactions Shown by Varieties.								
		Tweed Wonder.	Wellington Wonder.	Kentucky Wonder.	Black Valentine.	Brown Beauty (A.T.P.).	Staley's Surprise.	Startler Wax.	Hawkesbury Wonder.	Epicure.
767	Aust. 1	R	S	R	R	S	S	R	S	R
985	Aust. 2	R	S	R	S	R	S	S	S	R
986, 989, 990, 1034, 1036 ..	Aust. 3	R	R	R	S	R	R	S	S	R
987	Aust. 4	R	R	S	S	R	R	R	S	R
988, 1035 ..	Aust. 5	R	R	R	S	R	S	R	S	R
1026, 1028 ..	Aust. 6	R	R	R	S	R	S	S	S	R
1038	Aust. 7	S	S	R	R	S	R	R	S	R
1043	Aust. 8	S	S	R	S	S	S	S	S	R

It is seen that judging by these tests there is a wealth of resistant material available. Many of the varieties exhibit the climbing habit, but a number of the dwarf type are included. No association of resistance with any particular seed character could be found. Nothing regarding the real nature of host resistance is known.

TABLE 8.

A Comparison of the Determinations Made by Using the Two Different Sets of Varieties.

Race Designation.	
Second Test.	First Test.
Aust. 1	Aust. *B*
2	*D*
3	*E, F, G*
4	*F*
5	*E, H*
6	*F, G*
7	*C*
8	*G*
1	*B*
7	*C*
2	*D*
3, 5	*E*
3, 4, 6	*F*
3, 6, 8	*G*
5	*H*

In order to relate these results to those in which the smaller set of differentials was used (p. 75), the determinations have been simplified by making an empirical choice from the 132 varieties of a small group of nine of the better known varieties. The varieties Hawkesbury Wonder (susceptible throughout) and Epicure (resistant throughout) do not actually serve as differentials, but are included as useful commercial varieties, as well as types of their respective behaviours.

On this basis the determinations are as in Table 7.

On this basis eight races are sorted out. But they do not correspond with the eight previously determined with the other set of differentials. One of them (Aust. 3) comprises three of the former races (Aust. *E*, *F*, and *G*), and two of them (Aust. 6 and 7) each comprise two of the former races (Aust. *E* and *H*, and Aust. *F* and *G* respectively). A comparison is shown in Table 8.

An examination of the distribution of types on a space and/or time basis again gives no satisfying information.

Discussion.

A knowledge of the nature of the causal organism is essential to success in any attempt to control the disease. These studies were designed to throw some light on the host-parasite relationships that exist in the disease known as anthracnose of beans.

The first set of studies carried out between 1925 and 1928 revealed the presence in Australia of two physiologic races. One of them agreed with that recorded in U.S.A. as the beta race, and was present in 11 of the 12 isolates examined. The remaining one was different in its behaviour on one of the bean differential varieties, and has been styled Aust. *A*. This designation will not conflict with others in the literature where symbols such as Roman numerals are commonly used. From the small number of isolates no information of value could be got in regard to the distribution of the two races in time and space.

In the second set of studies, carried out between 1944 and 1952, 14 isolates were used in race determinations similar to those done previously. One came from Queensland, the rest from New South Wales. The presence was revealed of seven physiologic races, all different from the two found in the earlier work. They have been styled Aust. *B* to Aust. *H*.

During the interval between the two sets of studies there has been no appreciable change in the commercial varieties under cultivation. In other diseases, like the rusts of cereals, a marked change in the popularity of varieties because of their differential resistance has led to a marked change in the physiologic races present: a screening of the races has occurred, leading to the change in the rust flora as determined in the survey (Waterhouse, 1952). In this work on beans the change in the races determined cannot be explained in this way. The pathogen is seed-borne, and it is possible that the "new" races were introduced in seed brought from overseas. No sexual stage of the anthracnose fungus has been demonstrated, and so hybridization is ruled out. Hyphal fusions of differing mycelia could produce "new" races, but this happening has not been proved. Mutation of fungi has been demonstrated many times, and may be the explanation of the present happenings. What is important is that changes in a parasite as determined by its relationship with the host are constantly occurring. Where comparative studies are to be made, it is quite inadequate for morphological features to be regarded as a criterion of identity. Continuous checking of the physiological behaviour is necessary.

In such work the invariability of variation in the host is also of fundamental importance. Retention of genetic purity of the differential varieties used as hosts is essential. And if comparisons of results obtained by different workers are to be made, not only must the environmental conditions under which the tests are carried out be uniform, but the same genetically pure host material must be used as well.

The work reported herein shows clearly the need for these precautions. In a crop like beans, which are so widely grown, and in which seed is often sent from one country to another, confusion of names is not uncommon. In a new locality a local name may be substituted for the former name. A particular selection from imported material which is multiplied and established because of its particular characteristics may still carry the former name, whereas it may be of a different constitution from that of the original variety.

An example may be given. It was reported recently that Westralia beans were attacked by rust in New South Wales. Close examination showed that the "Westralia" crop which was rusted was not the real rust-resistant Westralia, although it appeared to be the same (Cass-Smith et al., 1954). Westralia itself is stated to have its origin

in a natural cross between Golden Harvest and a brown-seeded Kentucky Wonder (Cass-Smith et al., 1951). It was estimated that natural crossing occurred to the extent of 2%.

Our work has shown clearly the occurrence of natural crossing under Sydney metropolitan conditions, although only very limited observations have been possible. In 1954, from a pedigree row of Westralia, pods harvested from two plants yielded respectively mottled purple and light brown seeds. Six plants were produced; all were climbers, but they show clear differences in habit of growth, shape of leaf, and colour of flower. Further pedigree work with them is in progress, and may yield further information on the happening. It was known that several other varieties and crossbreds were growing some 10 to 12 feet away from the Westralia row.

In another instance, in 1953, a plant resembling Westralia was found in a row of this variety, also grown from pedigree seed. It produced rather flat streaked seeds—brownish-black streaks on a dun background—instead of the usual kidney-shaped white seeds of Westralia. Several of these streaked seeds were sown. They developed into strongly growing climbers which showed marked variation in flower colour, from white through pink to dark pink. The pods were long, but some were round, others flat in cross-section. The seed varied in shape and size as well as in colour; some were brown streaked with black, others brown, and two showed brown streaks on a cream background.

In this case it was known that the variety called "Tiger" was growing in close proximity to the Westralia row. It is a climber with dark pink flowers and flat pods bearing seeds which have brownish-black streaks on a dun background. It seems probable that in this case a natural cross between these two varieties had occurred. Numerous attempts have been made to cross these two by hand, but without success.

In areas where seed is produced on a commercial scale and where only one variety is under cultivation, the chances of natural crossing are greatly lessened. But in plant breeders' plots, where many varieties are grown in close proximity, it seems likely that the phenomenon occurs more frequently than is generally supposed.

Variations that are due to mutation must not be ruled out. A number of cases in our work has been noted in which chimaeric conditions affecting chlorophyll development have been present, but none has been shown to be heritable.

Selection of the varieties that are to be used in the host-parasite relationship studies is made on an empirical basis. It is not yet known what constitutes resistance to attack. But because of their genic make-up, some varieties show this character when tested with a wide series of isolates of the pathogen, whereas others are susceptible throughout the tests. Others again show differences in the reactions, and hence may be useful in classifying variations in the behaviour of different isolates. Because of differences in varieties under cultivation and differences in environmental conditions, it may be expected that with the passage of time there will be differences in the physiologic races present in different areas. Hence it is likely that the set of varieties selected as differentials for one country may not have the same usefulness elsewhere. In the cereal rust investigations it has been clearly shown that local conditions will often make it imperative to modify the normally-accepted set of differentials (Waterhouse, 1952).

This has recently been found in studies of bean rust in Australia (Waterhouse, 1954). The race of rust which is now so damaging to dwarf beans is not differentiated on the normally-accepted set of differentials, but is separated clearly when a local variety is added to the set.

Not only does a modified set of differentials give a more accurate picture of the host-parasite relationship that exists, but it generally gives far more assistance to the worker who is breeding for disease resistance.

In this work the normally-accepted set of six bean differentials has been used and eight physiologic races sorted out; they are styled Aust. *A* to Aust. *H*. They differ from the races recorded in U.S.A. as the alpha, beta, and gamma races. Using a totally different set of seven varieties, chosen as a result of testing more than 130 varieties

for their reactions, it happens that again eight races have been determined: they are styled Aust. 1 to Aust. 8. Whilst the results of the two sets of determinations show agreement in the case of three of the isolates, the others do not. Because of the relative ease in maintaining stocks of the second set of differentials in Australia, it is likely that this set will be found to be the more useful here. It may well be that further investigations will lead to modifications in this choice of varieties.

The simplified set of differentials just referred to came from the extended tests of varieties which showed that when the number of varieties tested is large, a very large number of variants of the pathogen may be distinguished. The tests show that there are numerous bean varieties available which were resistant to all the isolates used. A wider selection of isolates may well reduce this list of resistant varieties.

In recent communications (personal communications, 1954 and 1955), Mr. W. P. Cass-Smith, Plant Pathologist of the W.A. Department of Agriculture, states that a new situation has arisen in that State. Anthracnose of beans has recently shown up on Westralia, which on account of its strong rust resistance is now being grown late in the season. The temperatures are then relatively low, and anthracnose has been able to attack these crops of Westralia. In our tests the variety itself, as well as ten families from which it was ultimately selected and named, were quite resistant to all the isolates examined. It seems clear that a different race—or races—of *C. lindemuthianum* is present in Western Australia.

Because of its resistance to rust and its resistance to all the isolates of *C. lindemuthianum* tested, Westralia was selected as a parent in crosses and back-crosses with dwarf beans like Hawkesbury Wonder designed to combine the dual resistance with the commercially desirable characters of the dwarf type. This work is well under way, but the W.A. occurrence of anthracnose may mean that the Westralia resistance will be inadequate. If the anthracnose from Western Australia reaches New South Wales, this seems certain. Several other varieties, like Feijao, Little Navy, Resistant W.A. Kentucky Wonder, Harter's 814, and Scarlet Runner have also been used as parents having the dual resistance, but nothing is known about the basis of their resistance as compared with that of Westralia. Many other varieties also will be seen to combine the rust and anthracnose resistance.

From 200 pollinations of Hawkesbury Wonder with Westralia made between 1951 and 1954, only 10 have been successful. Very generally there is some development of the pod, but it soon stops growing and drops off. This is illustrated in Plate iii, in which the three basal flowers of the raceme were pollinated with Westralia, yielding tiny sterile pods in contrast to the normally-developed pods which were from selfed flowers. In the successful cases the pods developed were small and contained an average of only two seeds each. In one instance the crossed pod yielded seven seeds, but when they were grown, only four were crosses, the other three being straightforward Hawkesbury Wonder plants.

The F1 plants showed very poor development and produced an average of only 15 seeds each, thus curtailing very much the F2 examination; always some plants have been very feeble and have soon died. The segregating plants show marked sterility in seed-setting in some individuals, taking the form of tiny sterile seeds interspersed with normal seeds in a pod. Similar sterility effects have been found in the two crosses, Hawkesbury Wonder × W.A. Resistant Kentucky Wonder, and Hawkesbury Wonder × Kentucky Wonder Hybrid. The W.A. Resistant Kentucky Wonder is the supposed parent of Westralia which gave the latter its resistance. Counts involving 118 pods and 850 seeds gave a 20% sterility occurrence. There is a clear need for cytogenetical studies of these happenings.

The variety Scarlet Runner (*Phaseolus coccineus* L.) has been even more difficult to cross. It is still too soon to evaluate the results.

The late Mr. R. D. Wilson recorded (Wilson, 1950) striking differences between what he called Strain 1, to which the varieties Wellington Wonder and Tweed Wonder were resistant, and Strain 2, to which they were susceptible. The present work fully

substantiates this finding. It is clear that on the basis of the reactions given by additional varieties the two strains can be further split up.

An endeavour has been made to link up with the results reported by Egerton and Moreland (1916), Leach (1923), Rands and Brotherton (1925), Müller (1926), Schreiber (1932), Müller (1941), Reid (1943 and 1945), and Hubbeling (1946). In places some of the varieties used in the current work are included in the results reported, but there are so many differences in the varieties used that no valid comparisons can be made.

The amount of variation in *C. lindemuthianum* which has been so clearly established in Australia may well be further extended if further local studies are made. It is a happening that must always be taken fully into account in any programme designed to yield anthracnose-resistant varieties of beans.

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EXPLANATION OF PLATE III.

A and B : Resistant and susceptible varieties respectively, inoculated with *C. lindemuthianum*. $\times \frac{3}{4}$.

C : A raceme of a growing plant of Hawkesbury Wonder three weeks after pollination. The three basal flowers were pollinated with Westralia, and show the typical stunted pod development in contrast to the normal development of the other pods on the raceme from flowers which were self-pollinated. $\times \frac{1}{3}$.

THE PETROLOGY OF THE NORTHERN PART OF THE WYANGALA BATHYLITH.

By N. C. Stevens.

(Plate iv; two Text-figures.)

[Read 27th April, 1955.]

Synopsis.

Gneissic and massive granites of the Wyangala bathylith, central New South Wales, are intrusive into Ordovician and Silurian sediments and volcanic rocks as well as sporadically distributed diorite and amphibolite. Thermal metamorphism has affected chiefly the Ordovician tuffs and calcareous sediments, producing amphibole-plagioclase hornfelses. Chemical data suggest that the Cowra Granodiorite may belong to the Wyangala bathylith whereas the Pine Mount Granodiorite has less marked affinities with the other granitic rocks. The geological setting is not in keeping with large-scale granitization *in situ*, but a porphyritic gneissic phase is thought to have originated by granitization of sediments at depth. Finally, the age of the Wyangala bathylith and allied masses in S.E. New South Wales is discussed.

Introduction.

Between Cowra and Gunning in central and southern New South Wales a considerable area is occupied by a great granitic mass (termed in this paper the Wyangala bathylith), of which only the northern part, between Cowra and Frogmore, has been mapped and examined. The mapping has been of the nature of a detailed reconnaissance, and the following description of some of the interesting features of the bathylith will serve as an introduction to more detailed studies to be carried out in the future.

Along the 149th meridian the granites extend from Garland to Taylor's Flat (Plate iv), a distance of over 40 miles, but tongues may be traced east into the Abercrombie River region, so that the mass examined is linked with another elongated area of similar granites, which may be followed for 50 miles south of Bigga to Gunning and beyond. Further south are the Murrumbidgee and Kosciusko bathyliths, made up of strikingly similar rocks with similar chemical and mineralogical composition, structural characteristics and relations with the invaded rocks. Browne (1929, 1950) has assigned a late Silurian age to these concordant intrusions and has correlated them with similar granitic rocks as far apart as Wyalong and Hillgrove.

Prior to the present investigation, gneissic granites had been noted from Gunning and Wheeo, near Crookwell (Browne, 1929), but their extension north of these places was unknown. Harper (1929) had mapped a lenticular area of strongly gneissic granite at Wyangala Dam spillway, but did not realize that the surrounding granite had a distinct foliation. Reports on the Frogmore wolfram mines (Harper, 1919; Mulholland, 1950) pay little attention to the granites.

The Palaeozoic stratified rocks range from Middle Ordovician to Upper Devonian and include the previously described Walli Andesite (Stevens, 1952*a*) and the southern continuation of the Upper Devonian formation found in the Conimbla Mountains west of Cowra (Stevens, 1951). New formation names used on the map (Plate iv) are the Kenyu Formation and the Illunie Rhyolite. The Kenyu Formation, of probable Ordovician age, is exposed along the western margin of the Wyangala bathylith and consists of siltstones, slates, tuffs, andesites and occasional limestone lenses. The Illunie Rhyolite, which appears to overlie the Silurian sediments and porphyries east of Koorawatha, is chiefly made up of acid lavas and tuffs with indistinct flow banding and stratification. It is unconformably overlain by the Upper Devonian rocks, with a difference in strike of about 30°.

Alteration of the Country Rocks.

The Wyangala bathylith is intrusive into Ordovician rocks except in the south-west part near Gunnary, where the country rocks are Silurian porphyries, tuffs and breccias. On the eastern side of the area examined the Ordovician rocks are pelites and psammites, but on the western side and at the northern and southern margins of the main granite mass near Woodstock and Kenyu the country rocks are andesites, tuffs and siltstones.

The irregular distribution of contact metamorphosed rocks is related to the presence of tuffs, breccias and calcareous sediments, which were more susceptible to metamorphism than the pelitic and psammitic rocks.

Pelitic rocks show distinct thermal metamorphism on the Reid's Flat–Bigga Road and in the roof pendant near "Glen Rock" (north of Wyangala Dam). Close to the contact, cordierite is developed, giving the rocks a spotted appearance, but the interbedded sandstones have not suffered much change apart from the development of a little biotite in the matrix.

Two areas of knotted schists, one near Bolong and the other north of Frogmore, do not seem to be related to the granites which are exposed at present. The area near Bolong is a mile from the nearest exposed granite, and the area north of Frogmore, although close to the Forest Creek contact zone, trends at right angles to the contact and is outside the zone of hornfelses. Most of the rocks are silvery mica-schists, with spots or knots up to 12 mm. in diameter. Bedding is sometimes parallel to the schistosity, but contortions are often present in hand-specimens. Andalusite is sometimes preserved in the knots, but it is more commonly altered to sericitic aggregates. A bed of black slate interbedded with the schists has not been visibly affected, due possibly to the inhibitive effect of carbon, noted by Harker (1939), Turner (1948) and others.

The larger areas of hornfelses are found where the granites have invaded tuffs and calcareous sediments, e.g. at Forest Creek, between the Wyangala bathylith and the Pine Mount intrusion and near Kenyu.

The most interesting of these is the Forest Creek contact zone, between Springvale and Hovell's Creek. It is situated at the northern extremity of a belt of Ordovician slates and quartzites, bounded on either side by granites of the Wyangala bathylith. The granite-hornfels boundary is sharp but irregular (east-west); small intrusions of granite are separated from the main mass and the contact zone is intersected by dykes of acid granite and pegmatite.

The hornfelses are fine-grained greenish rocks containing amphibole, pyroxene, felspar, and, in some types, quartz or garnet. Original sedimentary bedding is sometimes evident, and one example of micro-current-bedding has been noted. A brecciated structure is visible in some of the more massive types.

The bedded hornfelses contain medium-green amphibole with varying amounts of grey pyroxene granules in darker bands which alternate with bands composed of andesine, microcline and sometimes quartz. Microcline may have been produced from original material in the sediments, but it also occurs in coarse grains associated with quartz, in which case these minerals are more likely to have been contributed by the granite.

Honey-coloured garnet (andradite-grossular) is present in some contact rocks which show relict fragmental structure. It is associated with large grains of twinned albite in certain areas and the two minerals may have been formed by the metamorphism of epidote and natrolite, occupying cavities (McLintock, 1915). Porphyroblasts of deep green amphibole are now largely replaced by granules of pale green pyroxene and are associated with biotite. The fine-grained areas consist of hornblende and granular plagioclase. Iron oxides are accessories in most of the hornfelses, and in the bedded types they are generally restricted to certain beds, notably those containing pyroxene.

The replacement of amphibole by pyroxene has been noted in several of these rocks, and it indicates two stages in metamorphism, the second stage being the more severe. The abundance of lime-bearing minerals and the presence of sedimentary

structures is consistent with the view that the original rocks were calcareous sandstones, tuffs and breccias. There is a possibility that some of the hornblende may have been original, as at least two different types are present, one of which is actinolitic. That all the amphibole is not original is proved by the occurrence of a yellowish-green variety in veins through the hornfelses.

Between the Wyangala bathylith and the Pine Mount intrusion there is a zone of hornfelses up to three-quarters of a mile wide to the west of "Melrose". The rocks are mainly fine-grained amphibole-plagioclase hornfelses, some of which exhibit bedding. Less metamorphosed siltstones, tuffs and andesites are also present.

The matrix of some of the tuffs near Coota Trig. contains biotite of metamorphic origin, indicating a less calcareous composition than usual. The plagioclase phenocrysts of the andesites are penetrated by needles and clusters of actinolite, and the groundmass has been recrystallized with the formation of fresh plagioclase and actinolitic amphibole.

This zone has no doubt suffered the contact effects of granites to the north and south, but in general the Wyangala bathylith is responsible for stronger metamorphism than the Pine Mount intrusion.

East of "Melrose", amphibole-hornfelses with phyllites and schists outcrop between the two intrusions in a wedge-shaped area, widening to the north-east. Plagioclase (andesine) and green hornblende are again the dominant minerals in the hornfelses, with pale green pyroxene in minor amounts. The felspar is present in rather large grains and also constitutes much of the finely granular groundmass. Some of these hornfelses were fragmental rocks, while others may have been basic lavas. Close to the gneissic granite the rocks have been extensively sheared; normal pelitic rocks have been converted to phyllites, and lavas and tuffs have given rise to quartz-chlorite-epidote-schists. The latter have a granular quartz base with porphyroblasts of pale green chlorite in which epidote has developed, probably as a result of the intrusion of the later Pine Mount Granodiorite. Epidotization and penetration by epidote veins is more noticeable further east near Milburn Creek, where small-scale current bedding can still be seen in some of the sediments.

The only amphibole-hornfelses found east of Hovell's Crek are restricted to a small area on Mt. Darling, where they are associated with basaltic rocks and interbedded with pelites and psammopelites. Amphibole has been developed in the groundmass of the basalts and both basalts and hornfelses are penetrated by veins of zoisite, which mineral occurs in irregular areas in the basalt, representing former amygdules.

Hornfelses derived from basic tuffs occupy areas between tongues of granite at Kenyu. The metamorphic rocks are fine-grained, containing epidote and actinolitic amphibole; the former in crystals and granular aggregates and the latter in needles. The proportions of the two minerals vary greatly and some cloudy felspar is usually present.

Along the western margin of the granite and gneiss to the east of the Woodstock-Wyangala Road, fine-grained amphibole-hornfelses are interbedded with slates and sandstones within a few hundred yards of the contact. The amphibole is a pale-coloured tremolite-actinolite and is associated with a strongly pleochroic pale yellow epidote and colourless zoisite showing anomalous interference colours. The felspar is oligoclase-andesine and contains abundant minute needles of amphibole. Zoisite or epidote occurs both in the main mass of the rock and in veins traversing it. Other hornfelses near by have bands of medium-green hornblende alternating with felspathic bands. Metamorphosed tuffs containing basalt fragments and actinolite in the matrix are found to the north near Waugoola Creek, and in the same area a banded, schistose psammopelite within the contact aureole is remarkable for the occurrence of pale blue pleochroic corundum (sapphire) in irregular grains. Each grain is surrounded by a sheath of sericite and is confined to the chlorite-rich parts of the chlorite sericite bands. The corundum does not seem to be detrital, for it is restricted to the silica-poor areas.

Granite contacts are generally quite sharp, and away from the thermal aureole the sedimentary rocks are of low metamorphic grade, with no sign of regional granitization.

Silicified sediments have been intimately penetrated by porphyritic granite on Old Woman Creek, north of "Glen Rock", but the contacts suggest the sediments were in a semi-plastic condition at the time of intrusion.

Pre-Granite Diorites and Amphibolites.

Diorites and hornblende-rich rocks of medium to coarse grain-size which antedate the Wyangala bathylith granites are found at Cocomingla, Bigga, "Melrose" and in the Parish of Purfleet (between Garland and the Abercrombie River). The two largest masses are at Bigga and Cocomingla, but only the latter has been studied in detail. At most localities there is ample field evidence that the granites are intrusive into the hornblende rocks, and at "Melrose" and Cocomingla the diorites have invaded sedimentary and volcanic rocks.

At Cocomingla the basic rocks outcrop over a sub-circular area with an average diameter of about one mile. They are surrounded by granite which is coarse and massive to the west and porphyritic and gneissic to the east. On Cocomingla Creek a marginal, non-gneissic phase of the granite sends tongues and narrow veins into the basic rocks, in places forming a network. Both granite and diorite invade highly contorted and metamorphosed sediments and a single occurrence of diorite intrusive into recrystallized andesite has been observed. Dark, fine-grained xenoliths, derived from diorite and sediments, appear in the granite close to the contact.

It has been possible to map two main rock types in the complex, viz., fine- to medium-grained diorite and porphyroblastic amphibolite, although each type shows some variation. The amphibolite occupies more than half the intrusion, outcropping mainly in the central and western parts, away from the contact with the porphyritic gneiss. It grades over a short distance into more even-grained diorites, but the contact is never a sharp one, and no well-defined xenoliths of one type occur in the other.

The hornblende porphyroblasts of the amphibolite, which may be up to 9 mm. long, are euhedral and enclose minerals of the groundmass as well as sphene, pyrite and occasional biotite and apatite. Inclusions of sphene are quite irregular and the amount varies antipathetically with that of quartz. Hornblende and pyroxene are often intergrown in the groundmass, but separate crystals of each may be enclosed in larger plates of andesine, microcline or quartz. The amounts of microcline and quartz vary greatly in the amphibolites, which in many respects resemble the appinites of the Glen Tilt complex, Perthshire (Deer, 1950).

The medium and fine-grained diorites show many of the same features as the coarser types and contain the same minerals in different proportions. Many are obviously crystalloblastic, yet others have few textural features that distinguish them from normal igneous rocks. In general, the crystalloblastic types have a mottled appearance in hand-specimen, and the larger poikiloblasts of felspar give rise to "lustre mottling". Some have a greater percentage of quartz and microcline with a corresponding decrease in ferromagnesians (especially pyroxene) and plagioclase. Epidotization has proceeded to a variable degree, affecting hornblende as well as andesine in the most altered rocks.

Pegmatitic veins are found towards the margin of the intrusion on Cocomingla Creek and along the Boorowa River. Unlike the later pegmatite dykes which intersect the intrusion, the veins have irregular shape and mostly indefinite boundaries. They are more often contained in the fine- and medium-grained diorites, which exhibit a fine-grained, hornblende-rich margin against the leucocratic phases, a feature similar to that produced in hornfels at the margin of granite of the Newry complex and ascribed to a "basic front" effect (Reynolds, 1949, see Plate 7).

The chief minerals in the leucocratic segregations are oligoclase-andesine, quartz and microcline, with some hornblende usually present. Quartz appears to be replacing plagioclase, which shows micro-faulting, with irregular quartz along fractures. Hornblende is euhedral, in some places attaining a length of 30 mm. It may have a semi-radiating arrangement or be confined to melanocratic bands.

Flat-lying dykes of aplite and pegmatite which intrude the basic rocks are more uniform in thickness and shape than the leucocratic phases noted above and are

distinguished mineralogically from the latter by the presence of muscovite and a more sodic plagioclase and the absence of hornblende. Field evidence suggests that the irregular acid segregations were formed at the same time as the crystallization of the diorite, whereas the regular dykes of aplite, pegmatite and quartz are post-granite.

In the Parish of Purfleet a narrow mass of fine-grained basic rock ranging from diorite to uralite-dolerite borders the granite at its contact with slates. The dolerite-slate contact is not exposed, but xenoliths of dolerite are present in the granite, which has been modified by a little hornblende close to the dolerite contact. The xenoliths contain much interstitial quartz; the hornblende has been recrystallized into actinolitic aggregates and a little biotite is developed near the margins of the xenoliths.

Near "Melrose" a small area of dioritic and hornblende-rich rocks occurs amongst metamorphosed tuffs, lavas and sediments between the Wyangala bathylith and the Pine Mount intrusion. The diorites are of even grain-size with subhedral hornblende and andesine, epidote and anhedral quartz. Orange-brown biotite has been developed in amphibole in one rock, presumably due to contact metamorphic effects of the younger granite. The amphibole has distinct orientation and parallel veins of zoisite traverse the specimen.

The Wyangala Bathylith.

The greater part of the bathylith is composed of plutonic rocks which fall between granite and granodiorite in composition. In the area examined the only hornblende-bearing granitic rocks within the bathylith occur as xenoliths; the more melanocratic granites usually contain a greater proportion of biotite and plagioclase. The phases mapped are: porphyritic gneiss, slightly gneissic granite, massive biotite-granite, and acid marginal types.

(i) *Porphyritic Gneiss.*

This rock appears to be restricted to the northern part of the Wyangala bathylith, and, as far as is known, is not developed in any other bathyliths of the same type in New South Wales. It is not merely a marginal phase but occupies an area eight miles wide between Springvale and Reid's Flat, across which foliation is noticeable and moderately uniform. An elongated belt of pelitic country rocks which interrupts the porphyritic gneiss at Mt. Darling is linked with another belt at Alston, and this widens south along the Lachlan Valley, separating the Wyangala and Bigga sections of the bathylith.

The porphyritic gneiss is generally of medium to coarse grain-size with phenocrysts (porphyroblasts?) of white potash felspar up to 8 cm. in length; the groundmass minerals are bluish quartz, lustrous biotite and white felspars. The biotite flakes lie in parallel planes, producing a platy flow structure or foliation. In the strongly foliated rocks biotite forms irregular layers bent around discoidal masses of quartz and felspar, and tabular phenocrysts and xenoliths are arranged with their longest axes parallel to the dip of the foliation planes.

In thin sections quartz is seen to occur in anhedral grains with highly undulose extinction and, in the more gneissic types, in streaky layers and granular aggregates between more resistant felspars. Similar features have been noted in gneissic granites from Wyalong (Watt, 1899) and Adelong (Vallance, 1954), and have been ascribed to post-consolidation effects involving recrystallization and plastic flow.

The felspars are in tabular, slightly rounded crystals and grains, and although some are cracked and bent in the more foliated rocks, they have not been granulated to such an extent as the quartz. Potash felspar usually exceeds plagioclase; it is commonly microcline which shows characteristic twinning, especially in the smaller grains and adjacent to granulated areas. A perthitic intergrowth is often apparent, but the intergrown albite makes up only a small percentage of the felspar.

The phenocrysts (or porphyroblasts) are also of microcline perthite, of the type known as shadow perthite (cf. Plate 6 of Emmons et al., 1953). They enclose anhedral quartz and more euhedral plagioclase and biotite, which are the same as in the groundmass. These inclusions may be arranged in one or more zones parallel to the crystal

margin and represent pauses in growth of the felspar; however, the phenocrysts are not mantled by sodic felspar, as in typical rapakivi granites.

Plagioclase forms subhedral, somewhat rounded crystals with sutured margins, and shows strain effects and some granulation. The composition varies from oligoclase in the normal rock to andesine in more melanocratic types, where it may exceed potash felspar in abundance.

Biotite tends to form large flakes in the less foliated rocks as a reduction in grain-size results from the movements which produced the foliation. Inclusions of rutile, apatite and zircon are common, and there is often alteration to chlorite and epidote. Muscovite is present only in the most acid gneisses, but sericite, as an alteration product, mottles the felspars, especially plagioclase.

A melanocratic gneiss at Bennett's Springs has oligoclase-andesine and microcline phenocrysts of varying size with abundant biotite in a mass of granular quartz and felspar. The excess biotite and the muscovite in this rock have been derived from mica-rich xenoliths of sedimentary origin, which are found in all stages of disintegration.

(ii) *Slightly Gneissic Granite.*

These rocks differ from the porphyritic gneiss in that they show less pronounced foliation and lack felspar phenocrysts. They outcrop on the northern side of the bathylith between Reid's Flat and Garland, and are found in apophyses between Frogmore and Taylor's Flat; other smaller occurrences are near Newham's Creek, surrounded by porphyritic gneiss, and south-west of Darby's Falls, where they form a narrow zone between porphyritic gneiss and massive biotite granite. Faint foliation is also visible at the margin of the massive granites north-west of Darby's Falls, and at one locality a few scattered phenocrysts are developed.

(iii) *Massive Biotite-Granite.*

Massive granites form a western border to the porphyritic gneiss up to four miles wide and twenty miles long between Kenyu and the northern end of the bathylith, and are also found between Reid's Flat and Bigga. West of the confluence of the Lachlan and Boorowa Rivers there is a gradation over several hundred yards from porphyritic gneiss through slightly gneissic granite to massive granite. There is no evidence of one type of granite having intruded the other.

The minerals of the massive granites are little different from those of the more gneissic rocks. Quartz, which loses the bluish tint characteristic of the gneisses, shows very few strain effects other than undulose extinction. Potash-felspar is reduced in amount and plagioclase is more abundant. Except for the presence of microcline, the rocks are somewhat similar to the hornblende-free granodiorite of Cowra (Stevens, 1952*b*), and contain similar but less abundant pelitic xenoliths to the east of that town.

(iv) *Acid Granite, Aplite and Granite-Porphyry.*

First to be noted are the two-mica gneissic granites, which are usually found at the margin of the porphyritic gneiss. They are cream- or pink-coloured, with obvious muscovite as well as granulated quartz, oligoclase, microcline and a little biotite. The micas occur together in clots which are often elongated, giving a planar structure.

Aplitic and acid granites outcrop where the bathylith narrows at Kenyu and to the north, muscovite-bearing porphyritic granites are found along the boundary between porphyritic gneiss and massive granite. Near Kenyu, dykes and apophyses of quartz-felspar-porphyry, granite and granite-porphyry project from the main mass of granite. A dyke of medium-grained, deuterically-altered granite runs parallel to the main contact and appears to have been responsible for the introduction of gold and copper near Godfrey's Creek, while acid gneissic granites occur close to the copper-bearing tungsten deposits at Frogmore and Reid's Flat.

Aplites are not as common as the coarser acid granites, but a number of dykes and veins has been noted, especially in well-exposed areas close to the bathylith margin (e.g. Wyangala Dam spillway). Aplite and pegmatite dykes appear at the northern extremity of the porphyritic gneiss between Milburn Creek and Mt. McDonald, and

around the dioritic mass at Cocomingla. The pegmatites often show graphic fabric and may contain muscovite or tourmaline as accessories. North of Reid's Flat a greisen with pink andalusite borders the gneissic granite, and is intersected by quartz veins containing wolframite.

(v) *Xenoliths.*

Xenoliths in the gneissic granites are mostly dark and fine-grained, with a biotite-felspar-quartz assemblage. Small porphyroblasts of white felspar and blue-grey quartz are common, and near Reid's Flat the former reach a size comparable with those in the gneiss itself.

In xenoliths found in coarse, slightly gneissic granite in the Newham's Creek area the fine-grained parts are composed of biotite flakes with distinct orientation, which wrap around tabular andesine and quartz grains. Some plagioclase porphyroblasts are composite with traces of oscillatory zoning, especially near the margins.

Intergranular quartz is developed in xenoliths enclosed in more gneissic granite and zones of granulation in the host rock split in the xenolith, which has been more resistant to deforming forces than the granite. Biotite is concentrated at the margins of such xenoliths, especially on the sides "sheltered" from shearing stress. Porphyroblasts are of microcline-perthite, oligoclase (with ill-defined twinning) and quartz (in irregular masses showing undulose extinction). Microcline, which encloses minerals of the matrix and optically oriented areas of quartz, is associated with plagioclase and surrounded by a quartz-albite (myrmekitic) border.

On Wyangala Dam spillway dark lenticular xenoliths contain porphyroblasts of microcline identical with those present in the gneiss. Another type of xenolith from Reid's Flat with large microcline porphyroblasts differs in that ferromagnesian minerals are almost absent in the groundmass. The latter is composed of irregular areas of strained and granulated quartz and equant crushed grains of microcline. In general, the more strongly foliated the granite, the more lenticular and oriented the xenoliths become.

Gneissic hornblende-bearing xenoliths occur in porphyritic gneiss in a road cutting south of Darby's Falls. Notable features are the oligoclase-andesine porphyroblasts and clots of biotite, hornblende and sphene; biotite is developing from hornblende by reaction with the more acid magma. Hornblende and sphene are uncommon in the gneisses and their presence links these xenoliths with the earlier diorites.

On the north-western side of the bathylith the massive granites contain unoriented xenoliths of a schistose appearance, with biotite, andesine and interstitial quartz and (?) cordierite. Similar pelitic xenoliths, sometimes containing spinel, almandine or sillimanite, have been found in the Cowra Granodiorite (Stevens, 1952*b*).

(vi) *Basic Dykes.*

Basic dykes intersect the gneissic granites near Wyangala Dam and Taylor's Flat. They are generally less than four feet wide and their directions are controlled by jointing in the granite.

The dyke-rocks are fine-grained dolerites with occasional andesine phenocrysts in a groundmass of felspar, epidote and chlorite.

(vii) *Structure in the Wyangala Bathylith.*

The most notable structural feature of the bathylith is the dominant north-south strike of the foliation and platy flow structure. There is some deviation from this direction only at the northern end of the bathylith between Milburn Creek and Mt. McDonald and south of Garland. In the former area the strike of the foliation is sub-parallel to the margins (which converge northwards) and in the latter it follows a N.E.–S.W. ridge of porphyritic gneiss.

In most places the foliation planes dip steeply to the west, though the dip is difficult to determine with certainty except with stable, well-exposed outcrops. The best exposures are at Wyangala Dam, where the porphyritic gneiss shows strongest foliation, dipping west at 65° to 70°. A linear parallelism of phenocrysts makes this a combined structure of planar and linear elements.

Zones of intense mylonitization parallel the foliation planes, producing compact, finely-banded rocks which superficially resemble slate beds, ranging from a mere film up to 50 feet or more in thickness. Secondary zones of crushing and fracture dip west at a shallower angle and acid veins in gneissic granites north of the dam follow the same two directions. Similar acid veins traverse both the gneiss and the later aplite dykes on the spillway.

The mylonitic rocks consist of layers of sericite and chlorite alternating with layers of granular quartz and felspar with larger, shattered microcline grains. The high degree of compaction of the rocks is due to impregnation by siliceous solutions which produced the acid veins in the gneiss and aplite.

Strongly foliated gneisses occur in two main zones east and west of Mt. Darling, converging northwards towards Mt. McDonald. Both are along gneiss-slate contacts for some part of their length and the foliation in the gneiss of the western zone is continuous with the zone of strong cleavage in the country rocks north of Mt. McDonald.

The stronger foliation of the gneisses is in part primary, and there is evidence that movements continued in the same zones after consolidation of the gneiss and intrusion of the aplites.

The Pine Mount Granodiorite.

East of Cowra and north-west of Wyangala Dam, granodiorite grading into hornblende-biotite-granite and quartz-mica-diorite, with associated aplites and acid phases, has invaded andesites, tuffs and slates of Ordovician age. Granodiorite is the main rock type, and the intrusion (a small bathylith or stock) is named after the most prominent hill in the area.

The intrusion is roughly elliptical, elongated east-west with a south-easterly prolongation to "Melrose", where it adjoins porphyritic gneiss of the Wyangala bathylith. The two bathyliths approach one another closely, being separated by only a few feet of phyllite at one point, but the actual contact is not exposed. Along the southern boundary the Pine Mount intrusion is separated from the Wyangala bathylith by a belt of metamorphosed tuffs about one mile wide, and for some distance the margins of the intrusions curve sympathetically. Apart from contacts with later dykes, no sharp contacts are visible within the intrusion, and changes in composition in the granitic rocks are gradual.

Hornblende-biotite-granite makes up the western part of the intrusion, with a fine-grained type in the north-west. The former grades into granodiorite as Pine Mount is approached, and this rock continues east and south with some coarser varieties south-east of Pine Mount. Quartz-mica-diorite makes up an apophysis in the north-east and related types are found near Milburn Creek in dykes invading the tuffs. Dykes of aplite are common near the margin of the intrusion, but pegmatite is rare.

Xenoliths are notable along the eastern margin of the intrusion, and good exposures of the sharp contact may be seen in Milburn Creek, where several small hornfelsed roof pendants are preserved. Away from effects of the Wyangala bathylith, thermal metamorphism has not extended far from the margin of the Pine Mount intrusion.

The granites and granodiorites of the northern part of the intrusion differ from those of the Wyangala bathylith in the following respects: (1) the constituent minerals show no strain effects; (2) the potash felspar is orthoclase, usually heavily kaolinized; (3) plagioclase greatly exceeds orthoclase; and (4) hornblende is present.

However, in the south-east prolongation of the intrusion, granodiorite from a prominent hill west of "Melrose" shows signs of stress in thin sections, although there is no apparent lineation in outcrops. Microcline is present, and quartz exhibits undulose extinction and slight granulation at grain boundaries.

Orientation of minerals becomes stronger as the boundary of the porphyritic gneiss is approached. It is likely that these structures are secondary, having been impressed on the Pine Mount intrusion after consolidation. The maximum effect is concentrated at the boundary between the two bathyliths, where schistose rocks have been produced.

The hornblende-bearing granites and granodiorites which adjoin the Wyangala bathylith in the upper part of Milburn Creek are similar to those of the Pine Mount

intrusion. Unfortunately, field relations between these rocks and the neighbouring slightly gneissic granites are not clear.

At the northern end of this intrusion near Lucan, there is a great variety of fine-grained granites, aplites and granophyres with some quartz-felspar-porphyries and hornblende-porphyrites. Many of the rocks appear to be hybrids between granodiorite and more acid phases and it is impossible to map them separately. The same diversity of rock types is found at the head of Waugoola Creek, but in the narrow section of the intrusion south of Milburn Creek only medium-grained granodiorite is present.

Most of the rocks from this eastern equivalent of the Pine Mount Granodiorite have a very faint parallel orientation of ferromagnesian minerals and sub-parallel fracturing of quartz grains. The fracture planes are close to vertical and trend north-south, but the orientation of the ferromagnesian minerals has not been investigated.

The massive, hornblende-bearing, granitic rocks are quite different from the biotite-rich and frequently gneissic rocks of the Wyangala bathylith, and from a consideration of structural features it is likely that the Pine Mount intrusion is the younger.

Chemical Data.

Five granitic rocks from this area have been analysed—three from the Wyangala bathylith and two from the Pine Mount intrusion. Analyses of these are given in Table 1 together with the Cowra Granodiorite and granites from the Murrumbidgee, Kosciusko and Adelong bathyliths.

The analysed "granites" of the Wyangala bathylith have SiO_2 percentages ranging from 66 to 76; but the most acid variety (which is comparable with the "white gneiss" of the Murrumbidgee bathylith) is exceptional, and the average SiO_2 percentage for the whole bathylith would be less than 70. CaO is variable but generally rather high (especially in the porphyritic gneiss), and potash exceeds soda in Wyangala bathylith rocks and those of comparable intrusions. The granodiorites from Cowra and the Pine Mount intrusion have a higher soda : potash ratio. Of these, the hornblende-biotite-granite from Rocky Peak (near the south-east margin of the Pine Mount intrusion) is closest to the typical rock of the Wyangala bathylith in chemical composition.

Table 1.

Chemical Analyses of Granitic Rocks of the Wyangala and Related Bathyliths and of the Cowra and Pine Mount Intrusions.

	1	2	3	4	5	6	7	8	9	10
SiO_2	67·64	66·71	72·03	76·08	68·93	70·31	67·67	74·99	65·75	72·30
Al_2O_3	14·54	15·52	16·29	12·93	15·80	18·68	16·02	10·44	16·63	14·50
Fe_2O_3	2·24	0·63	0·39	0·70	0·69	0·63	0·56	n.d.	1·41	0·73
FeO	4·05	3·74	1·73	0·90	3·75	1·83	3·79	5·58	3·29	1·98
MgO	1·13	0·76	0·40	0·53	1·94	1·10	2·20	0·09	0·90	0·52
CaO	2·70	3·83	1·61	0·52	2·50	2·22	2·12	0·50	4·08	2·60
Na_2O	3·04	2·86	2·65	2·31	1·88	1·37	2·86	2·66	4·90	3·63
K_2O	3·12	3·58	3·52	5·26	2·37	3·32	3·41	4·82	1·30	2·53
H_2O+	0·93	0·56	0·73	0·33	0·65	0·65	0·57	0·52	0·59	0·62
H_2O-	0·23	0·14	0·12	0·19	0·10	0·09	0·18	0·17	0·19	0·13
TiO_2	0·94	1·25	0·32	0·35	0·90	0·35	0·71	tr.	1·23	0·36
P_2O_5	0·12	n.d.	n.d.	0·12	n.d.	0·06	—	—	n.d.	n.d.
MnO	0·04	0·05	0·03	0·06	0·09	—	0·03	tr.	0·20	0·19
	100·72	99·63	99·82	100·28	99·60	100·61	100·12	99·77	100·47	100·09

1, Cowra Granodiorite, 4½ miles N. of Cowra.—2, Porphyritic gneiss, Darby's Falls. Anal. J. Pyle.—3, Coarse, slightly gneissic granite, Newham's Creek.—4, Gneissic granite, Wyangala Dam. Anal. W. A. Greig. *Dept. Mines N.S.W. Ann. Rept.* for 1932, p. 96.—5, Gneissic granodiorite, Charlotte Pass, Mt. Kosciusko.—6, Coarse biotite-granite. A phase of the "Blue Gneiss" (Murrumbidgee bathylith). Shannon's Flat, W.N.W. of Cooma. Anal. G. A. Joplin. Quoted by T. G. Vallance, Proc. Linn. Soc. N.S.W., 78 (1953): 210.—7, Granodiorite, portion 62, par. Wallace, Co. Wynyard. Anal. T. G. Vallance, *ibid.*—8, White gneiss, Bunyan. Anal. G. A. Joplin, *ibid.*, 68 (1943): 172.—9, Fine-grained granodiorite, E. of Holmwood (near Cowra).—10, Hornblende-biotite-granite, Rocky Peak, S. of Pine Mount.

Analyses 2, 3 and 4 are of rocks from the Wyangala bathylith; 9 and 10 from the Pine Mount intrusion. Analyses 1, 3–5, 9 and 10 by N. C. Stevens.

On an Or. Cor. : Ab : An. Fem. diagram (Text-fig. 1) the three analysed representatives of the Wyangala bathylith are relatively acid, falling near the Or. Cor. : Ab edge. The gneissic granodiorite from Kosciusko and several others from the Murrumbidgee bathylith and north-east Victoria are more centrally situated and thus more basic. The Cowra Granodiorite and related rocks fall close to this field, but the granodiorites of the Pine Mount intrusion do not. Dissimilarities are not so well shown in the AFC diagram (Text-fig. 2) because of the relatively high CaO in the porphyritic gneiss. As lime-bearing ferromagnesian minerals are absent in the rock, the lime must be contained in plagioclase.

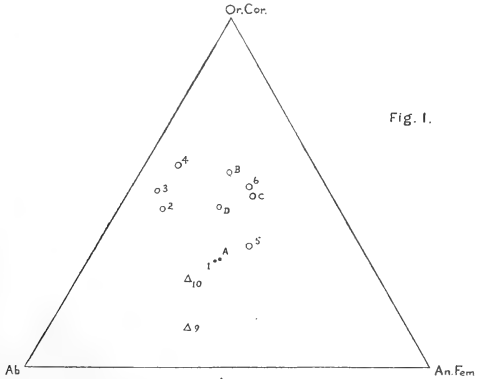

Fig. 1.

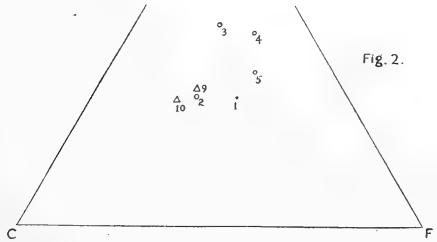

Fig. 2.

Text-fig. 1.—Or. Cor : Ab : An. Fem diagram for granitic rocks of the Wyangala and related bathyliths and of the Cowra and Pine Mount intrusions. 1-6, 9 and 10 as in Table 1.

A, Canowindra Porphyry, 6 miles E. of Canowindra. Stevens, Proc. Linn. Soc. N.S.W., 77 (1952) : 134.

B, Quartz-mica-diorite (hornblende-free), Cooma. Anal. G. A. Joplin. *Ibid.*, 68 (1943) : 171.

C, Quartz-diorite, Cooma. Anal. E. A. Burnard and E. T. Wallace. Quoted by Joplin, *ibid.*, 68 : 171.

D, Granite, Koetong mass, V. Anal. C. M. Tattam, *Bull. Geol. Surv. Vict.*, 52 (1939) : 38.

O = gneissic granites; ● = Cowra Granodiorite and the related Canowindra Porphyry; △ = Pine Mount intrusion.

Text-fig. 2.—AFC diagram for granitic rocks of the Wyangala and related bathyliths and of the Cowra and Pine Mount intrusions. 1-5, 9 and 10 as in Table 1.

O = gneissic granites; ● = Cowra Granodiorite and the related Canowindra Porphyry; △ = Pine Mount intrusion.

Origin and Age of the Plutonic Rocks.

In this part of New South Wales the major intrusions of granitic rocks are found to the south of Cowra and Woodstock, while to the north of these towns the intrusions are mostly of minor importance (excluding the sill-like Cowra Granodiorite and Canowindra Porphyry).

In discussing the mode of emplacement of the granites, we must consider whether there was intrusion of magma with displacement and assimilation of the country rock or whether the granites were formed *in situ* by transformation of the sedimentary rocks with or without the aid of emanations.

To express an opinion on which of these processes obtained, the nature of the granite contacts and the degree of metamorphism of the metasediments must be examined critically. In every place where the granite-sediment contact is exposed, the boundaries are sharp, with no transitional zone of felspathized rocks, migmatites or extensive metamorphic zones. In some places the pelites are scarcely altered a few yards from the contact. It is true that, in other places (e.g. Old Woman Creek) there seems to be an intimate mixture of granite and sediment, but the contact, like that of Sea Point, S. Africa (Reed, 1951), "is a moved one, showing mechanical mixing of softened-up slate and viscous granite". The geological setting is not in keeping with large-scale granitization *in situ*.

Certain features of the porphyritic gneiss, such as the porphyroblasts in the xenoliths and the identical felspars in the gneiss, suggest an origin by granitization; but there are no porphyroblasts developed in the country rocks at the granite margins. From a detailed study of xenoliths in the Cowra intrusion (Stevens, 1952*b*) it is suggested that the xenoliths in the porphyritic gneiss are of sedimentary origin. If so, the grade of metamorphism is much higher and of a different type from that found at the exposed contacts. The evidence suggests that the porphyritic gneiss has not been generated *in situ*, but has moved into its present position from a much deeper level, where it was most likely produced by granitization of sediments.

"Termier maintained that if a granite is surrounded by a narrow aureole it is certain that the granite has come from somewhere else, ready-made; if it is surrounded by a vast metamorphic aureole it has been formed in place while the neighbouring rocks were regionally metamorphosed" (Reed, 1948). In eastern New South Wales granites surrounded by extensive metamorphic zones have been described by Joplin (1942, 1947) and Vallance (1953, 1954). Both authors postulate a magma to have been present, and Vallance (1954) cites chemical evidence to suggest that even these granitic masses were introduced into their present position rather than formed *in situ*. They have been termed synchronous bathyliths (Browne, 1931), injected during the main compressional movement, whereas later, higher-level plutons are called subsequent; Joplin (1948) has termed the intermediate type (of which the Wyangala bathylith is an example) "quasi-synchronous". These bathyliths are generally concordant with the country rocks and are marked by a gneissic foliation which may be strongest close to the margin (Den Tex, 1954) or have irregular distribution (Vallance, 1954).

In the case of the Wyangala bathylith the foliation is strongest close to the centrally-situated slate belts south of Wyangala, but granites at the north-eastern margin of the bathylith are only faintly gneissic and those at the western margin are quite massive. Granites of the apophyses and those close to east-west contacts are also less gneissic than rocks well within the bathylith. The marginal slightly gneissic and massive phases may be explained as successively later intrusions, injected after the main compressional forces had waned, a theory which is supported on the western side of the bathylith by acid and porphyritic marginal phases along the boundary of massive granite and porphyritic gneiss. However, east of Frogmore there is a progression from porphyritic gneiss through slightly gneissic granite to massive granite at the southern end of an apophysis, and there is little likelihood of separate intrusions.

The north-south foliation seems to have been produced by compressional forces from the west, the magma having been squeezed up westerly-dipping cleavage planes produced earlier in the country rocks by forces from the same direction. At either end of the bathylith where irregular east-west contacts caused turbulence in the magma there was less tendency for the rocks to become foliated. In U.S.A. the Boulder bathylith (Graut and Balk, 1934) shows somewhat similar structures with hornblende crystals forming lines pitching in constant directions at contacts. It is thought to have risen from considerable depths.

In contrast to the other granitic intrusions, the Pine Mount Granodiorite has its greatest length east-west, so that in general it cuts across the strike of the country rocks and emplacement seems to have been controlled by east-west joints. As it closely adjoins the gneissic granites it is unlikely that it represents a higher level of intrusion, unless large-scale uplift followed by a long period of erosion is postulated. It is suggested, therefore, that the granodiorite was intruded during a static period after the consolidation of the Wyangala bathylith, the magma having been basified slightly by hybridism with earlier basic rocks or by assimilation of andesites. The hornblende-bearing granodiorite east of the Woodstock–Wyangala road has been formed from the same magma and has consolidated under conditions of weak compression. These rocks merge into slightly gneissic granites of the Wyangala bathylith, and bear a closer relation to them than does the Pine Mount intrusion.

The origin of the pre-granite diorite and amphibolite will be fully discussed in a later paper; at this stage it may be noted that the association of similar basic rocks with gneissic granites at a number of places in south-eastern New South Wales indicates that the acid and basic rocks are genetically related. There is, however, no evidence that the basic rocks have been derived from sediments as a by-product of large-scale granitization.

The Wyangala gneissic granites invade strata as young as Silurian, but at no place are they in contact with Devonian or Late Palaeozoic rocks, so that their age cannot be determined accurately from field evidence. No granitic intrusions have been found in the large areas of Upper Devonian rocks between Orange and Boorowa, and it is quite possible that all the granites in this region are pre-Upper Devonian, associated with the Bowning or Tabberabberan orogenies.

There are strong lithological similarities between the gneissic granites of Wyangala and those of the Murrumbidgee bathylith. The supposed late Silurian age of the latter (Browne, 1929) depends partly on lithological similarities with pre-Middle Devonian granitic rocks of North Gippsland and partly on dissimilarities between gneissic granites and massive granites presumed to be associated with Tabberabberan and Kanimblan orogenies.

Joplin (1948) admits that gneissic and massive granites may be formed at the same level during different phases of the same orogenic epoch, and in the Wyangala bathylith gneissic and massive types are found side by side and even grade into one another with no sign of intrusive relations between them.

Upper Devonian strata rest on the massive Windermere Granodiorite at Murringo North, and on the northern extremity of the Young bathylith at Broula. The Windermere Granodiorite is intrusive into the Illunie Rhyolite, which may perhaps be correlated with the Bulls' Camp Rhyolite near Orange (Stevens and Packham, 1953). These rhyolites are thought to be Lower Devonian, but there does not seem to be any unconformity between them and the underlying Silurian strata. The Bowning orogeny, if it affected these rocks, must have taken place after the extrusion of the rhyolites and probably before deposition of the Garra beds. In the region under consideration the unconformity representing the Bowning orogeny is very slight compared with the Tabberabberan unconformity and there is no reason why the pre-Upper Devonian granites should not have been injected during the Tabberabberan orogeny.

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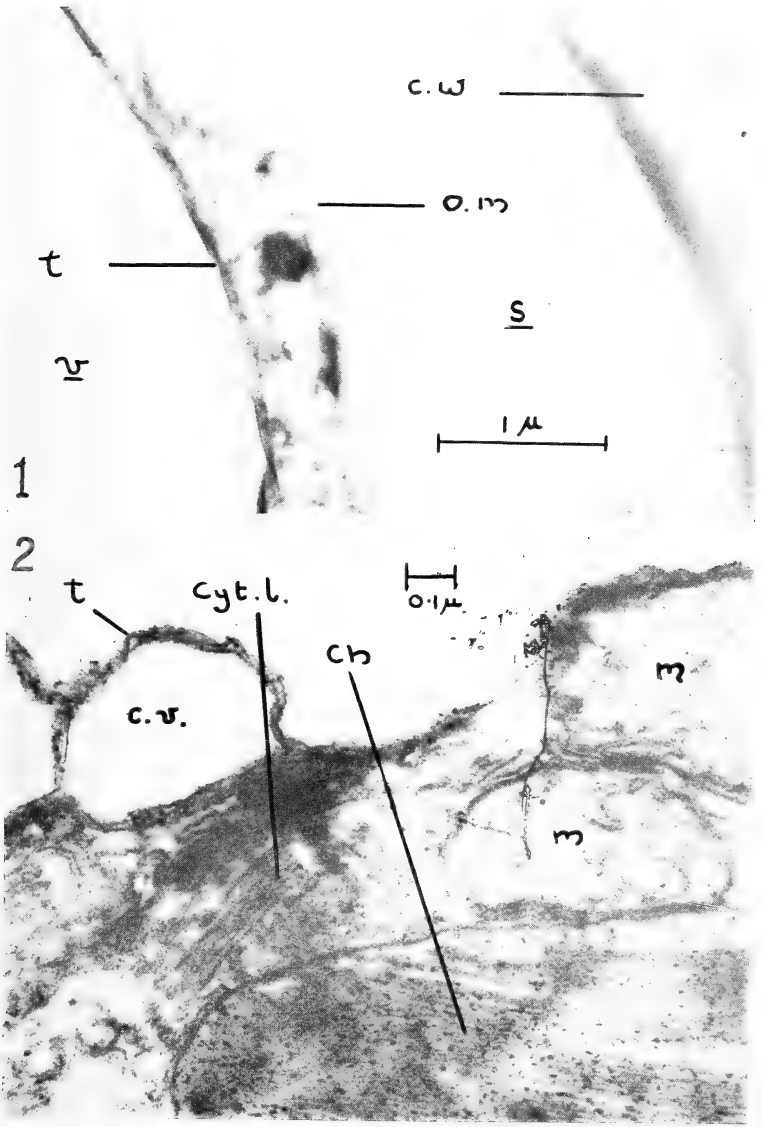
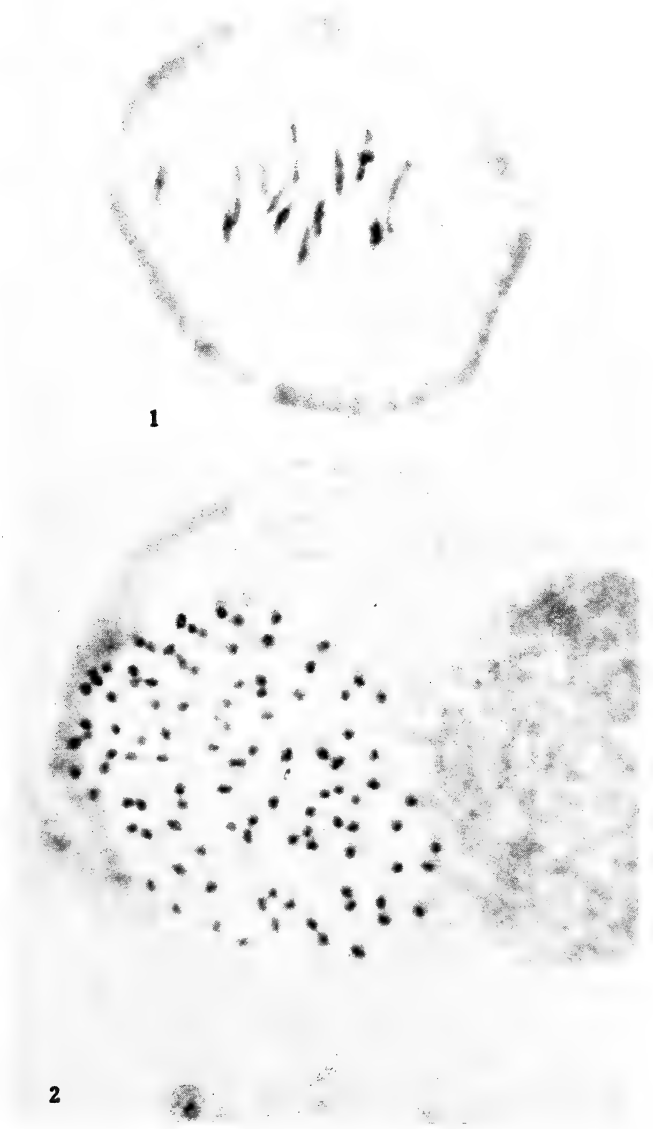
EXPLANATION OF PLATE IV.

Geological map of the northern part of the Wyangala Bathylith.

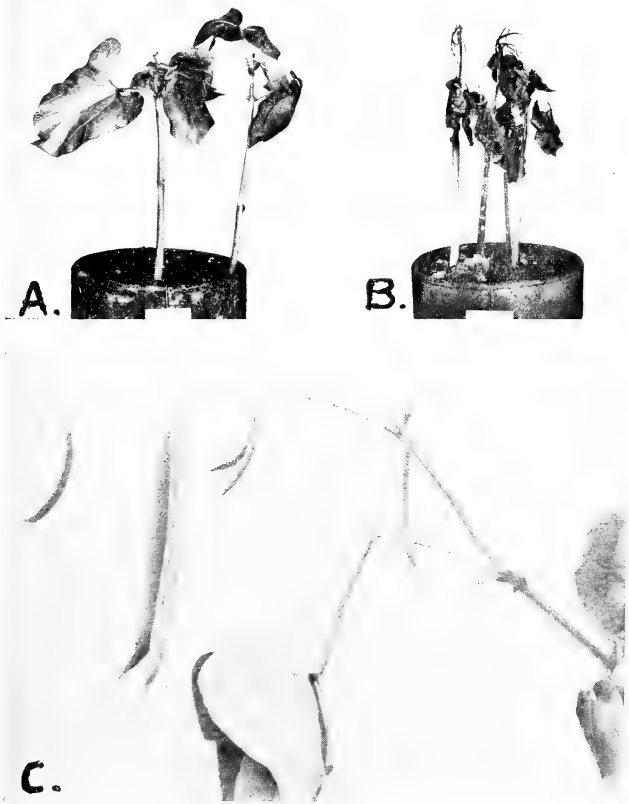


Electron micrographs of (1) Beetroot, (2) *Nitella* sp.



Drimys insipida. 1, Meiosis, microspore mother cell; 2, mitosis, tapetal cell.

Polystichum fallax, n. sp.



Bean anthracnose in Australia.

NITROGEN ECONOMY IN SEMI-ARID PLANT COMMUNITIES.

Part II. The Non-Symbiotic Nitrogen-Fixing Organisms.

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(One Text-figure.)

[Read 25th May, 1955.]

Synopsis.

The nitrogen-fixing bacteria (*Azotobacter* and *Clostridium*), and the blue-green algae *Nostoc* and *Anabaena* spp. have been recorded from some semi-arid soils. *Azotobacter* occurs in very low numbers. Soils of heavy texture supporting a grassland of *Astrebla pectinata* or scrubs of *Acacia victoriae* appear to contain *Azotobacter* consistently. Soils from the rocky ridges supporting mulga scrub contain *Azotobacter* if a vegetative cover is present, but with increasing erosion the populations of the organisms decrease. Soils from the stable dunes appear to lack *Azotobacter,* except in the mallee where the organic content of the soil is relatively high. In one case only (a soil of heavy texture) did the number of *Azotobacter* cells per gram exceed 50. The possible maximum contribution to the N. capital of the soil through the activity of *Azotobacter* is of the order of 0·1 lb. per acre per annum. Low organic matter, high summer temperatures, low soil moisture and in a few cases low phosphate and calcium levels militate against the successful activity of *Azotobacter.*

Clostridia were not studied quantitatively. They were present in most soils investigated.

Those blue-green algae capable of fixing nitrogen occur in most communities. The numbers vary tremendously and appear not to be correlated with any environmental factor. The highest frequency of these organisms occurs under translucent quartz stones. It is estimated that their possible maximum contribution to the nitrogen capital is of the order of 3 lb. N. per acre per annum.

According to these quantitative data the non-symbiotic organisms fix nitrogen at a very slow rate which is insignificant over short periods of time.

Introduction.

In the first paper of this series (Beadle and Tchan, 1955) an account of the ecological conditions in some of the semi-arid communities in western New South Wales was given, and chemical data were presented to show that under the present conditions of grazing (which frequently initiates erosion) serious losses of soil organic matter and nitrogen have been sustained. Replacement of soil nitrogen, which is vital to the pastoral industry, cannot be satisfactorily attempted until we have a thorough understanding of the nitrogen sources for the community. For this reason a survey has been made of the nitrogen-fixing organisms that occur in the soils.

The present paper deals with the non-symbiotic N-fixing microflora. An attempt is made to indicate, firstly, to what extent these organisms augment the nitrogen capital of the plant community, and, secondly, to what extent erosion and the attendant loss of organic matter have affected the microbial populations: both the non-symbiotic heterotrophic bacteria *Azotobacter* and *Clostridium* and the photosynthetic organisms (members of the Myxophyceae) are considered.

Soils from a greater number of communities than discussed in our first paper were investigated for nitrogen-fixing organisms. These communities which are named in Table 1 have been described by Beadle (1948).

Techniques.

Field Sampling.—For each sample eight spots within a circumscribed area were selected and about 10–20 gm. of soil from each spot were removed as a core to a depth of about 3 inches. The eight small samples were mixed in a previously sterilized screw-top jar. The mixed samples were numbered, as indicated in Table 1.

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Azotobacter.—For estimates of frequency, the method described by Tchan (1952) was used. All positive growths on the plates were checked by microscopic examination. Martin's medium, as recommended by Collins (1952), was used as a check. Mineral requirements of *Azotobacter* growing in the various soils were determined with the Winogradsky-Ziemiecka (1928) soil plate technique. All the above tests were done in duplicate.

Clostridium.—Only qualitative tests were made. Winogradsky's (1949) deep liquid medium with sucrose was used.

Photosynthetic organisms.—For identification, the organisms were examined microscopically. Generic determinations (*Nostoc* and *Anabaena*) only were made.

Frequencies of the organisms in the soil were estimated by the counting technique, by dilution on to Allison and Hoover's (1935) medium in agar gel.

Results.

Non-Symbiotic Bacteria.

No quantitative data are available for *Clostridium*. These organisms occurred in nearly all samples investigated. Their contribution as nitrogen-fixers is probably of the same order as that made by *Azotobacter* as discussed below; indeed, it is probably less, in view of the fact that clostridia are anaerobic, and such conditions probably rarely obtain for any significant length of time.

Azotobacter was found to occur in only 11 of the 30 samples examined (Table 1). When present, the numbers were invariably low. This result was obtained using both Tchan's and Martin's techniques. The latter technique gave no significant difference from the former, which is in contrast to Collins' (1952) statement regarding the superiority of Martin's medium.

As far as distribution is concerned, the data in Table 1 bring out the following significant points. Firstly, on the rocky ridges *Azotobacter* was present in all samples collected from areas where some mulga is still present. These few remaining mulgas may, therefore, have some significance in protecting the soil from the direct rays of the sun whereby *Azotobacter* can survive because of the less extreme temperature conditions (see below). Areas not protected by mulga (four samples) show the presence of *Azotobacter* in two samples. Since each sample is a mixture from eight spots, it is difficult to draw more precise conclusions from the data available. It is noteworthy (and unexpected) that sample 24, in which *Azotobacter* was recorded, comes from bare areas. Whether these areas have been bare for a year only, or for many years, cannot be stated. It may well be that only one of the eight sites making up sample 24 contained *Azotobacter*, and this site has recently become bare. In contrast to the rocky ridges, soils from the stable dunes all lack *Azotobacter*, even when a good cover of mulga still exists. We hesitate, however, to state that this is universal in the dune country, in view of the fact that only one sample from a good mulga stand (eight sites mixed) has been examined. Soils from the Regeneration Area* at Broken Hill likewise lack *Azotobacter*, with one exception—and this sample comes from bare areas with a low organic content. However, since the Regeneration Area lies close to irrigated orchard and plantation, the single positive record may well be an accidental migrant from the well-watered areas.

The single mallee soil examined contained *Azotobacter* (this soil has the highest organic carbon content of all). In the case of the *Casuarina* scrub, no *Azotobacter* was recorded in all five samples (40 sites). This observation supports the view (above) that *Azotobacter* is absent on stable dune country with the exception of the mallee. All of the three heavy-textured soils examined (these support *Acacia victoriae* or the Mitchell grass, *Astrebla pectinata*) contain *Azotobacter*.

Quantitative estimates for the frequency of *Azotobacter* show that in only one case did more than 50 cells per gram occur.

* This area has been enclosed against stock for some 17 years. Originally wind-blown sand, it is now well vegetated with patches of *Cassia* and patches of grass and herbage, with bare spaces distributed non-randomly among the vegetation.

On theoretical grounds a low frequency of *Azotobacter* is expected. pH conditions alone can be regarded as suitable for the growth of *Azotobacter* (pH of all soils lie within the range 6·0 to 8·0).

Temperature is an important factor in determining the survival of *Azotobacter* cells. Waksman (1952) states that the temperature range for *Azotobacter* is 10° to 40° C. There is no doubt that, even when an area is well vegetated with herbage and scrub, both air and soil surface temperatures exceed 40° C. regularly during the summer. When vegetation is removed, much higher temperatures occur, as indicated in our first paper. Therefore, it is most probable that under virgin conditions *Azotobacter* cells led a precarious existence, while on bare soil, and particularly after erosion, survival is most improbable.

Martin (1940) has stated that concentrations of salt above 3,000 p.p.m. limit the activity of or kill *Azotobacter* cells. The concentrations in the soils investigated indicate that salts are not an inhibiting factor in these soils.

Soil moisture is another very important factor. Under semi-arid conditions, surface layers of the soil are dry for weeks, or even months on end, and during these periods microbial activity of all descriptions must proceed at negligible rates.

The low percentage of soil organic matter as a source of energy for *Azotobacter* must also reduce the activity of these organisms. To investigate this point quantitatively, sixteen soils, previously used for the pot culture experiment described in our first paper, which had been kept moist under glass-house conditions in Sydney for a period of sixty days, were selected for study; eight of these had been shown to contain *Azotobacter* cells, the remaining eight apparently lacked *Azotobacter* according to the previous tests. These soils had received supplies of all nutrients except nitrogen. The soils were plated again, but only four out of the sixteen gave positive growth of *Azotobacter*; two of these came from samples from which the organism had previously been recorded, the other two from soils which apparently lacked *Azotobacter*. The frequency did not increase. It appears that the low number of cells in the soils accounts for the non-appearance of *Azotobacter* in the second tests; the appearance of the two positive occurrences in the second tests may be due to contamination, or they could have been missed in the first tests because of very low numbers. Since mineral nutrients were adequate in this experiment, the poor growth of *Azotobacter* can be attributed to the low supply of organic matter. This was confirmed by the next experiment in which sucrose was added as a carbohydrate source for the bacteria. Thirty soils, which were inoculated with *Azotobacter* to insure that the organisms were present, were plated using the soil plate technique, with 1% sucrose as an energy supply. Twenty-four of these produced colonies; five of these in comparatively large numbers, thirteen in moderate numbers, six few. The remaining six produced no colonies; all of these six lacked *Azotobacter* according to the previous tests.

It appears then that six of the soils are unsuitable for the growth of *Azotobacter* for some other reason. Mineral supply was tested, the six soils being replated with the addition of phosphate, phosphate + calcium, and calcium alone. Four responded to added phosphate; one of these soils came from the wind-blown, sandy deposit in the Regeneration Area at Broken Hill, three from the *Casuarina* scrub. Two responded to the addition of both calcium and phosphate; one of these came from a scald in the mulga scrub on the stable dunes, the other from a secondary dune.

Photosynthetic Organisms.

Of the thirty samples of soil investigated for N-fixing blue-green algae, 18 contained significant numbers of species of *Nostoc* and *Anabaena*, both of which genera are considered to fix atmospheric N. The occurrence of these organisms in the various samples investigated is given in Table 1. In some cases, quantitative estimations were made, and these indicate that the algal cells, when they occur, are far more abundant than those of *Azotobacter*, and since algal cells are several times as large as *Azotobacter* cells, they may be of significance in the nitrogen economy. The figures as they are presented are misleading in so far as the number quoted refers to the occurrence of

TABLE 1.

The Occurrence of Azotobacter *and of Blue-green Algae in Selected Communities from Semi-arid New South Wales.*

Community	Mulga scrub.							*Casuarina* scrub.		Mallee.	Regeneration Area* (formerly mulga scrub).			*Acacia victoriae* scrub.	*Astrebla pectinata* grassland.	
Habitat ..	Rocky ridges.				Stable dunes.			Stable dunes.		Stable dunes.	Foothills of ridges, slope slight.			Creek.	Flat plain.	
Condition of community	Some mulga dead.		Mulga all dead.	Bare soil.	Some mulga dead.	Most mulga dead.	All mulga dead.	Well timbered.	Grassed areas within scrub.	Near-virgin.	*Cassia* dominant.	Grass and herbs dominant.	Bare soil.	Shrubs vigorous.	Well grassed.	Pseudo scald.
Erosion ..	Negligible.	Slight water —.	Significant water —.	Severe water.	Slight wind —.	Severe wind —.	Completely scalded.	Slight wind.	Severe wind	None.	*	*	*	None.	Slight.	
Sample No.	1 2	19 22	20 21 23	24	5	4 7	3 6	27 29 28	26 30	31	12 13 14	10 11	8 9	16	17	18
Azotobacter (presence + or absence —, or No. of cells per gram)	+ +	+ +	+ — —	+	—	— —	— —	— — —	— —	+	— — +	— —	— —	+	130	+
Blue-green algae .. (No. of cells per gram, or presence + or absence —)	+ 70	120 —	140 + —	—	+	— 330	440 +	400 130 +	— —	250	— 150 60	+ —	+ 70	—	—	—

* See footnote, p. 98.

cells in each gram of soil sampled to a depth of 3 inches, i.e. the algal cells which are concentrated in the top few millimetres of soil because light can penetrate only to this depth (Tchan and Whitehouse, 1953) have been mixed throughout the entire sample. According to the records in Table 1, there appears to be no correlation whatsoever between habitat and the occurrence of algae. For example, algae are present in some timbered areas, absent in others; on some scalds, but not on others. It is highly probable that in this changeable and extreme climate, population numbers fluctuate tremendously.

The most favourable habitat for algae in semi-arid climates appears to be on the under-surface of quartz pebbles which are light in colour. Dark-coloured pebbles lack algae on their under-surfaces. Light-coloured pebbles occur commonly on the treeless plains (gibber country), and in some of the mulga scrub on the ridges. The light-coloured or white quartz allows the light to penetrate, and at the same time, since the stones are partly buried, the water régime underneath is more favourable for algal growth than that on the exposed soil surface. Furthermore, during the night when air temperature drops, the under-surface of the pebble would act as a condensation apparatus. Similar growths have been recorded in U.S.A. by Williams (1943), who describes an accumulation of peat up to a thickness of $\frac{1}{4}$ inch (pebble peat) under stones.

A survey of the light-coloured pebbles showed that both size of stone and depth of burial are important as far as algal population is concerned. In all size classes pebbles which do not touch the surface or which merely rest on the surface support few algae. Those whose lower surfaces are in contact with the soil, and particularly when slightly buried, support the most algae. Size also is important, the larger the stone, the greater the algal population when the under-surface is in contact with or buried in the soil (Table 2).

TABLE 2.

Percentage Algal-cover on the Under-surface of Light-coloured Stones. Data Collected at Fowler's Gap in the Mulga Scrub (Rocky Ridge).

Diameter of Stones.	Number Examined.	Percentage of Stones with			
		0–10% Algal Cover.	11–30% Algal Cover.	About 50% Algal Cover.	80–100% Algal Cover.
0·5–1·0 cm.	480	37·4	8·4	12·5	41·7
1·0–1·5 cm.	580	20·0	17·1	24·0	37·9
3·0–3·5 cm.	120	0	16·7	16·7	66·6

In the area of stony country investigated at Fowler's Gap it was estimated that one-third to one-half of the stones are white (in some areas all stones are white, in others white stones are lacking), and that these white stones cover about one-sixth of the soil surface. (See Text-fig. 1.) Since half of the stone surface is algal-covered, about one-twelfth of the soil is covered by algae.

By incubating in Allison and Hoover's N-free medium, a positive culture of blue-green algae was obtained. In most cases species of *Nostoc* were predominant, in a few cases species of *Anabaena*. Other algae (members of the Chlorophyceae) occur if non-selective media containing combined nitrogen are used (the algal flora of part of the area has been listed in Moewus, 1952). By subculturing, colonies of the blue-greens free from *Azotobacter* and *Clostridium* were obtained, and these cultures fixed nitrogen under laboratory conditions.

DISCUSSION AND CONCLUSIONS.

The low frequency of *Azotobacter* (less than 50 cells per gram of soil) on the ranges supporting mulga scrub, and the apparent lack of *Azotobacter* from the sandy soils of the stable dunes (except the mallee) suggest that these organisms contribute

little to the nitrogen capital of the soil. In the most favourable habitat (in pockets of soil among rocks on the stony ridges) a population of 50 cells per gram with optimum external conditions could fix a maximum of 0·1 pound of nitrogen per acre per annum. (The calculation is similar to Jensen's (1950).) In the field, where general conditions are never optimum, the actual fixation is therefore insignificant.

This conclusion is in agreement with the findings of other workers, both in Australia and America. Jensen (1940), for example, reports similar low numbers of *Azotobacter* cells for the wheat belt in New South Wales, where ecological conditions are more favourable for the growth and activity of *Azotobacter* than in the semi-arid soils. He draws the general conclusion that for the wheat soils, *Azotobacter* fixes an inconsequential amount of nitrogen. For the Sydney district where moisture, temperature

Text-fig. 1.—Showing the distribution and sizes of wind-polished quartz pebbles lying on desert loam soil at Fowler's Gap, north of Broken Hill. The tracks running across the photo have been made by sheep travelling to and from a nearby watering place.

and soil organic matter, but not soil nutrients, are more favourable for *Azotobacter*, populations of 6,000–1,000 cells per gram have been recorded (Jensen, 1940; Tchan, 1953). Even at this much higher frequency this organism is still not regarded as being a significant contributor. Similar conclusions have been drawn for the semi-arid soils of the United States. Vandecaveye and Moodie (quoted by Russell, 1950) have found that the *Azotobacter* population is invariably low, and also that it may be apparently absent for some years and then become common again.

The presence of *Azotobacter* in the semi-arid country indicates, at least, that the organisms are capable of living under the present conditions, though there is little doubt that they merely exist. The contribution to the nitrogen capital made by algae is possibly higher than that made by *Azotobacter*. The algae are perhaps the more widespread, and since their cells are the larger, their contribution may be of greater

significance, particularly when localized colonies develop, as under pebbles. Using these pebbled areas to obtain a maximum value, we compute the following: It is estimated that 1,000 algal cells per gram of soil fixing nitrogen actively for 40 days in the year would add to the soil 1 lb. of nitrogen per acre. Since the highest concentrations of algae are of the order of 2,000–3,000 cells per gram, the theoretical maximum annual increment is 2–3 lb. per acre.

The total theoretical annual increment of nitrogen fixed by *Azotobacter* and N-fixing algae is, therefore, of the order of 3 lb., if both groups of organisms fixed to their maximum in the same area. This figure takes no account of denitrification, which may be active. This figure, as the following calculation will show, is too small to be detected by the Kjeldahl technique. The amount of nitrogen in the surface 6 inches of a soil with 1% organic carbon (0·1% N.) is about 2,000 lb. per acre. The Kjeldahl technique has an accuracy of about 2%. Consequently, the experimental error (which involves a possible error of ± 40 lb. N. per acre) is far higher than the theoretical maximum increment of N. contributed by the organisms under investigation. For this reason N. increment studies for these organisms cannot be done on a yearly basis; indeed, if the organisms are fixing nitrogen as calculated a period of some forty years would be required to give a contribution in excess of the Kjeldahl error.

As a general conclusion the following statement may be made: Under the existing conditions the non-symbiotic organisms fix nitrogen at a very slow rate; indeed in some areas the annual increment to the nitrogen capital must approach zero, for example, in badly eroded areas where the soil organic matter is extremely low and where moisture and temperature conditions are such that both bacteria and algae would either be absent or active for insignificant periods of time.

As far as the activity of the organisms in the virgin communities is concerned no reliable quantitative data can be presented because today no community is virgin. However, since accelerated erosion has greatly decreased organic levels and at the same time has intensified the severity of the adverse climatic conditions, we may assume that the activity of the nitrogen-fixing organisms in virgin areas could be higher than the rates quoted above. Nevertheless, even if we double the already generous estimate a very low annual increment still results. Whether this small annual addition accumulating over decades or even centuries accounts for the whole of the nitrogen capital in the community cannot yet be stated, nor can the relative importance of the non-symbiotic organisms in comparison with the symbiotic organisms or the addition of fixed nitrogen in rainfall be assessed until further research is done. These other sources of nitrogen will be discussed in subsequent papers.

Acknowledgements.

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NOTES ON AUSTRALASIAN SIMULIIDAE (DIPTERA). IV.

By M. J. Mackerras and I. M. Mackerras, Queensland Institute of Medical Research, Brisbane.

(Twenty-three Text-figures.)

[Read 25th May, 1955.]

Synopsis.

Two new species are described, *Simulium torresianum* n. sp. from Badu in the Torres Straits, and *Austrosimulium magnum* n. sp. from North Queensland. New distribution recorded includes *Simulium ornatipes* Sk. from New Caledonia and two species from Flinders Is. in Bass Strait.

The material here recorded, including two interesting new species, has been accumulated since Part III of this series was published (These Proceedings, 77: 104-113, 1952).

Genus Cnephia End.

Cnephia strenua M. & M.

New distribution.—Queensland: Little Crystal Ck., 45 m. N. of Townsville, 1,100 ft., November-December; Elabana Falls, Lamington Plateau, South Queensland, 2,600 ft., December. Previously known only from the type locality near Cairns.

Cnephia aurantiacum (Tonn.).

New distribution.—Bass Strait: Mt. Strzelecki, Flinders Is., January (Mykytowycz). The larvae and pupae show some divergence from mainland and Tasmanian specimens, and may represent a distinct race.

Cnephia tonnoiri orientalis M. & M.

New distribution.—South Australia: Myponga Ck., September; Sellick's Hill, October; Scott's Bottom, September; Brownhill Ck., September (all coll. Lines). Not previously known from that State. The localities lie on the peninsula south of Adelaide, and it is interesting that all the pupae examined belong to the eastern race, and not to the typical race which seems to be confined to the south-western corner of Western Australia.

Cnephia umbratorum (Tonn.).

New distribution.—Victoria: Gould, September (Douglas); McKenzie Falls, Marysville, September (Neboiss); King Parrott Ck., Kinglake West, October (Neboiss); Boho, nr. Benalla, August (Douglas). Previously known only from Fern Tree Gully, Beaconsfield, Narbethong and Buxton in the same State.

Cnephia terebrans (Tonn.).

New distribution.—Victoria: Bacchus Marsh, October; McKenzie and Turret Falls, Marysville, September; Middle Ck., Beaufort, October (all coll. Neboiss). A.C.T.: Black Mt., in light trap, September (Dyce). Previously known only from Sassafras in Victoria and Mt. Canobolas in New South Wales.

The records from the light trap set up by Mr. Dyce on the roof of the C.S.I.R.O. laboratory at Canberra are the first of their kind in this country. In addition to a female *C. terebrans*, the collections included a male *C. tonnoiri orientalis*, female *Austrosimulium cornutum*, and series of *A. furiosum*, *A. victoriae* and *A. bancrofti*.

Cnephia fergusoni (Tonn.).

New distribution.—Victoria: Cohuna, September (Read); Turret Falls, Marysville, September (Neboiss). Not previously recorded from the State.

Genus Simulium Latr.

Simulium ornatipes Sk.

New distribution.—New Caledonia: Dothio R., east coast, May (Dumbleton). Previously known from New Guinea and the mainland of Australia. Many new records from Victoria show it to be widely distributed in that State (previously listed only from Merbein, Beechworth, Glen Rowan and Bacchus Marsh).

Simulium aureonigrum M. & M.

New distribution.—Queensland: Little Crystal Ck., 45 m. N. of Townsville, November-December. Previously known only from the type locality near Cairns.

Simulium inornatum M. & M.

New distribution.—Victoria: Boho, nr. Benalla, August (Douglas). Previously known from south Queensland and eastern New South Wales.

Simulium melatum Wh.

New distribution.—Victoria: Lavington Ck., nr. Albury, October (Myers); Ovens R., Bright, March (Myers); Harry's Ck., Violet Town (Douglas); Spring Ck., Bacchus Marsh, October (Neboiss); Boolarra, August (Douglas); Hiawatha, May, August (Douglas); Grieg's Ck., Yarram, January (Douglas). Previously recorded in the State only from Yarrawonga and Beechworth.

Simulium torresianum, n. sp.

Types.—Holotype ♀, allotype ♂, morphotype larva and pupa, from small, clear creek on Badu Is., Torres Straits, April, in Division of Entomology, C.S.I.R.O., Canberra, A.C.T.

Distinctive Features.

Belongs to the *clathrinum* group, characterized by the presence of a pre-alar zone of pale, scale-like hairs on the pleura.

A small, dark species, 2·5 mm. long, with silvery hairs on scutum, and the pale zone on hind metatarsus somewhat obscure.

♀: Rather like *S. inornatum*, but distinguished from all Australian members of the group by the bare, rather shiny sixth to eighth abdominal tergites, and almost complete absence of pale hairs on the abdomen, there being only small patches at the sides of the third and fourth tergites.

♂: Distinguished by the upper facets of the eyes being remarkably enlarged, the fifth and subsequent tergites of the abdomen largely bare and shining, and the free margin of the anterior part of the phallosome strongly convex. *Pupa*: Respiratory filaments six, much longer than in *S. nicholsoni* and *S. faheyi*, and their mode of branching different. *Larva*: Resembles *S. aureonigrum* in having compound rectal gills, well developed ventral papillae, and lateral dark scales anterior to the circlet; but the head pattern and gill-spot are quite different.

This species could be *S. oculatum* (End.), which was described from the Huon Gulf in New Guinea, and which also has greatly enlarged upper facets in the male and a similar abdominal pattern. The hairs on the scutum, however, are said to be golden, and the claws without teeth. *S. oculatum* cannot be recognized with any certainty until its group characters and early stages are known, so it seems best to treat our form as distinct.

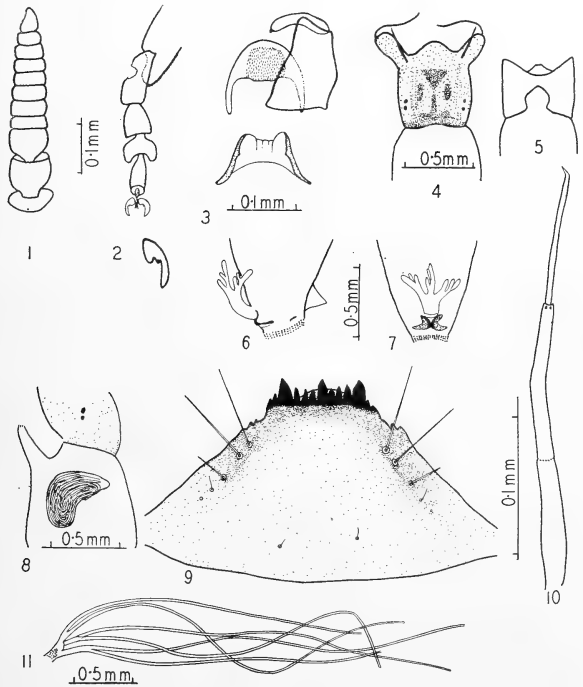
Female.

Head. Frons tapering towards antennae, about one-sixth of head width at narrowest point, dark greyish-brown, with sparse creamy-white hairs. Face similar. Antennae (Text-fig. 1) short; basal two segments brownish-yellow; remainder dark greyish-brown, with silvery tomentum. Proboscis and palpi dark brown.

Thorax. Scutum dark greyish-brown, with sparse silvery hairs which are denser posteriorly (specimen rubbed). Scutellum dark brown, with long, dark, bristly hairs. Postscutellum bare. Pleurae dark greyish-brown, with silvery scales on the pre-alar area. *Legs* dark brown, with brown and black hairs; basal four-fifths of hind metatarsus

rather obscurely pale. Calcipala well developed; claws with minute sub-basal tooth (Text-fig. 2). *Wings* clear, veins brown; halteres with brown stem and brownish-cream knob.

Abdomen brownish-black. First segment pale medially, with brown fringe. Second to fifth tergites with dark brown tomentum and short brown hairs; sixth to eighth bare, dark greyish-brown, shining rather dully, and with inconspicuous hairs; there is a small, almost linear patch of creamy-white hairs laterally near the posterior margins of the third and fourth tergites. Venter dull.



Text-figs. 1-11.—*Simulium torresianum*, n. sp.

1, antenna of female; 2, hind tarsus and claw of female; 3, hypopygium of male, the posterior part of the phallosome shown separately below; 4, 5, head of larva; 6, 7, posterior end of larva; 8, gill-spot of larva; 9, submentum; 10, antenna; 11, respiratory horn of pupa.

Male.

Head. Eyes contiguous, upper eye-facets very greatly enlarged, up to 0·050 mm. in diameter, in 10–12 rows. Antennae slender; basal two segments yellowish-brown, remainder dark brown. Face dark greyish-brown, with white hairs. Proboscis and palpi dark greyish-brown.

Thorax. As in female; scutum covered with long silvery hairs. Legs and wings as in female, but veins and stem of halteres paler.

Abdomen. First tergite dark brown, with dark brown fringe; second and third tergites covered with black tomentum and brown hairs; fourth and subsequent tergites with median patch of blackish tomentum bearing bright brown hairs, large on fourth and decreasing in size on more apical segments, and with the remainder of the tergites

shining greyish-black, with black hairs. Venter black. This abdominal pattern is distinctive among the males of the Australian species of the group. Hypopygium as in other members of the group, except that the anterior part of the phallosome bulges posteriorly (Text-fig. 3), much as in *S. peregrinum*.

Cocoon.

Length 3 mm. Coarsely woven; anterior border rather irregular, with only an indication of a central dorsal projection; no collar.

Pupa.

Length 2·5–3 mm. Head and thorax ornamented with microscopic semilunar or triangular projections. Hairs long and fine. Abdominal chaetotaxy similar to that of other Australian members of the genus.

Respiratory organ (Text-fig. 11) consists of a very short stem, ornamented with minute spines, and giving off three main branches, each of which divides again close to the main stem, so that there are six very long, delicate filaments on each side. The tips of all those measured had been broken off, but some still measured 3·2 mm., so that the intact filaments must be as long as or longer than the body.

Larva.

Length, 5·5–6 mm. Greyish-brown, mottled. Head pale; pattern on dorsum very variable, usually of a cruciate type (Text-fig. 4). Antennae normal (Text-fig. 10). Ventral incisure deep (Text-fig. 5). Submentum with 13 teeth (Text-fig. 9).

Gill-spot large, roughly triangular, with broadly rounded angles; the antero-ventral angle is nearly a right angle, and the opposite side is indented (Text-fig. 8). The long, delicate filaments sweep down and round posteriorly; they do not continue to coil spirally, but after making one complete circle they double back rather sharply upon themselves. One or more of the slender tips may sometimes be seen projecting above the indentation.

Rectal gills compound, each with two or three branches. There is a brown patch or streak laterally anterior to the circlet, as in *S. aureonigrum* and related species. Anal sclerite not particularly large, and of the usual X-shape (Text-fig. 7). Ventral papillae large (Text-fig. 6). Posterior circlet with about nine or ten spines per row, the rows quite widely spaced.

Biology.

Larvae and pupae were found on dead twigs in a small, clear, rather sluggish creek with a sandy bottom. Habits of adults unknown.

Distribution.—Known only from the type locality on the island of Badu in the Torres Straits.

Genus AUSTROSIMULIUM Tonn.

AUSTROSIMULIUM MONTANUM M. & M.

New distribution.—Victoria: Boho, nr. Benalla, August (Douglas); Rocky Valley Ck., Bogong High Plains, January (Fennessy); Christmas Hills, nr. Melbourne, September (Douglas); Greig's Creek, Yarrum, September (Douglas); Wilson's Promontory, January, March (Douglas). Previously known in that State only from Sassafras, Narbethong and Buxton.

AUSTROSIMULIUM VICTORIAE (Roub.).

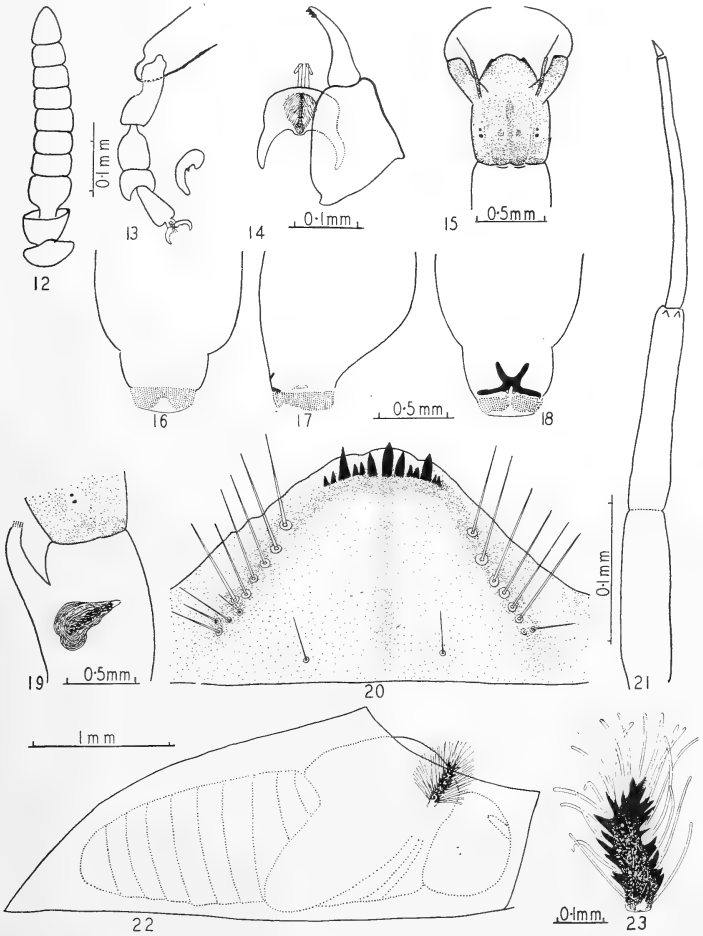
New distribution.—Bass Strait: Mt. Strzelecki, Flinders Is., January (Mykytowycz). Larvae only were collected. It would be interesting to know whether pupae on the island have cocoons of the mainland or Tasmanian type.

AUSTROSIMULIUM TORRENTIUM Tonn.

New distribution.—Victoria: Ovens R., Bright, March (Myers); Livingston Ck., Omeo, December (McMillan). Not previously recorded from that State. *A. torrentium* var. was found at both localities, *A. torrentium hilli* only at Bright.

AUSTROSIMULIUM MAGNUM, n. sp.

Types. Holotype ♀, allotype ♂, morphotype larva and pupa, from Little Crystal Ck., 45 m. N. of Townsville, North Queensland, 1,100 ft., November-December, in Division of Entomology, C.S.I.R.O., Canberra, A.C.T.



Text-figs. 12-23.—*Austrosimulium magnum*, n. sp.

12, antenna of female; 13, hind tarsus of female; 14, hypopygium of male; 15, head of larva; 16-18, posterior end of larva, ventral, lateral and dorsal views; 19, gill-spot of larva; 20, submentum; 21, antenna; 22, cocoon and pupa; 23, respiratory horn of pupa.

Distinctive Features.

A large species, 3–3·5 mm. long. ♀: Distinguished from all other known Australian members of the genus by having a pattern of white hairs (not white tomentum) on the abdominal tergites. ♂: Also distinguished by having white abdominal hairs, which are

less conspicuous and more scattered than in the female. *Cocoon*: Resembles *A. bancrofti* in texture and in possessing a well-marked collar. *Pupa*: Respiratory horn resembles that of several species of the *mirabile* group; however the combination of a black, spiny pupal horn and a *bancrofti*-like collar on the cocoon is quite distinctive. *A. torrentium* also has a spiny horn and collared cocoon, but its cocoon is peculiarly broad and flat, with the thorax of the pupa fitting firmly into the opening and held in position by modified hairs. *Larva*: Distinguished by its large size, *Cnephia*-like shape, and extremely wide posterior circlet.

The affinities of this species are difficult to assess. It has distinctly *Cnephia*-like features in the vestiture of the abdomen of the adult, the shape of the larva, the form of its posterior sclerite, and its very wide posterior circlet. In other respects, however, it is a true *Austrosimulium*. Within the genus, it resembles the *mirabile* group in the toothed claws of the female (though the tooth is in a different position) and in the spiny respiratory horn of the pupa. In other characters (frons and antennae of female, hypopygium of male, cocoon, pupal chaetotaxy, absence of ventral papillae on larva) it conforms to the *bancrofti* group, the definition of which, however, will need to be modified in the following terms in order to include it:

> Claws of female simple or with sub-basal tooth; abdomen with pattern of pale tomentum or hairs. Larva without chitinous ring anterior to circlet; ventral papillae absent.

Female.

Head. Frons wide, tapering towards antennae, about one-fourth head width at narrow part, with greyish tomentum and creamy-white hairs. Face grey, with white hairs. Antennae with first three segments creamy to yellowish, the third darkening apically; remainder dark brown, with short dark and scattered silvery hairs; the second and third segments are the largest, but are not unusually enlarged (Text-fig. 12). Proboscis and palpi dark brown, with dark hairs, and with some silvery ones anteriorly on proboscis.

Thorax. Scutum and scutellum dark brown, densely covered with small golden to creamy-golden hairs. Postscutellum rather shining, bare, dark brown, with brilliant silvery reflections. Pleurae brown, with silvery reflections, particularly in the pre-alar area. *Legs* dark brown, with dark brown and creamy golden hairs; hind femora and tibiae robust. Calcipala well developed; claws with a small tooth lying between basal swelling and shaft (Text-fig. 13). *Wings* clear, with brown veins; halteres with stem brown, knob creamy.

Abdomen. First segment brown, with white to creamy-yellow fringe; second to fourth and part of fifth tergites velvety black; remainder dark grey, bare but not shining; all with conspicuous white hairs, which are particularly concentrated in certain areas to form a fairly well defined pattern. In most specimens, there is an apical white band on the second tergite, a median white vitta, sometimes interrupted, from the apex of the third to the apex of the fifth, and white apical bands on the same tergites; the sixth and subsequent tergites are more diffusely white. The pattern varies in extent and arrangement, but the white hairs are always conspicuous, and form a unique character in Australian members of the genus. Venter dark brown, the apices of the sternites paler, with silvery hairs which tend to be arranged in bands.

Male.

Head. Upper facets of eyes moderately enlarged, up to 0·035 mm. Antennae more slender than in female, and basal segments darker. Face grey, with silvery reflections; proboscis and palpi blackish-brown.

Thorax. Scutum velvety black, densely covered with short, rich golden hairs, which are longer and more conspicuous in front of and on the scutellum. Pleurae and legs darker than in female.

Abdomen. First segment black, with dark brown fringe laterally, and some shorter, paler hairs medially; remaining tergites velvety black, with scattered white hairs, which do not form the definite pattern seen in the female, but are relatively conspicuous

on either side of the median line at the base of the second tergite and more laterally on subsequent tergites. The extent of the white hairs is variable, but the zone on the second tergite seems always to be present. Hypopygium (Text-fig. 14) without striking features; style with two or three terminal spines. The shape of the anterior part of the phallosome, the arrangement of its ventral setulae, and the irregular posterior part of the phallosome, with denticles not detectable, suggest affinities with the *bancrofti* rather than the *furiosum* group.

Cocoon.

Length 3·5 mm. Finely woven, with neat rolled edge; there is a well developed collar, but no trace of central dorsal projection (Text-fig. 22).

Pupa.

Length 3·2 mm. The integument of the head and thorax is ornamented with minute flat tubercles. On the head, there is a broad median bare streak bearing very few tubercles, but they are densely massed on each side. On the thorax, there is a row of tubercles on each side of the median suture, then a relatively bare streak on each side, gradually merging into the thickly covered lateral areas. The tubercles are grouped in rosettes of 4–6. There are two pairs of cephalic hairs with fairly stiff bases and fine tapering ends. The thoracic hairs are similar, except for the most posterior of the dorsocentrals, which are modified to form strong hooks.

The abdominal chaetotaxy resembles that of the *bancrofti* and *furiosum* groups, as distinct from the *mirabile* group. The first and second tergites bear five pairs of fairly stiff hairs; the third and fourth have four pairs of strong hooks, directed forwards and situated near the mid line; the fifth to seventh each has four pairs of similar hooks, which are more widely spaced than those on the third and fourth; the eighth has six pairs of minute, curly, anchoring hairs, and the ninth a pair of tiny terminal hooklets. The ventral surface appears bare.

The respiratory organ consists of a short, black, spiny stem, from all parts of which there arise fairly short, fine filaments (Text-fig. 23).

Larva.

Length 7–8 mm. Greyish-brown, with pale area postero-ventrally. Head heavily chitinized. Pattern on dorsum a median dark longitudinal streak, merging into a dark transverse band along the posterior border. There are two dark patches, one on each side of the mid line. Anteriorly, the fronto-clypeus is raised into a dark ridge on each side running antero-medially from near the base of the antennae (Text-fig. 15). Similar ridges have been seen in some *Cnephia* larvae, particularly in *C. strenua*. The antennae (Text-fig. 21) are dark brown, and project well beyond the basal piece of the fan. The submentum (Text-fig. 20)) contains 13 teeth, of which the central and the third from the end on each side are the largest; there are 8 to 10 pairs of submental hairs.

The gill-spot is of the typical *Austrosimulium* kind, with the black shiny horn showing clearly, and the very numerous fine filaments curving round anteriorly (Text-fig. 19).

Anal gills simple. Ventral papillae absent. Posterior sclerite well developed. It has the usual backwardly-directed strut of the genus, but flattened and almost entirely hidden behind the upright part of the sclerite. There are two backwardly-directed triangular projections on each side of the mid line, which are less heavily chitinized than the remainder, and there is also a brownish patch on each side just ventral to the ends of the horizontal part of the sclerite. The posterior circlet is particularly well developed. It consists of very numerous rows of closely set spines, there being up to 32 spines per row. The circlet varies in width, being narrowed in the mid ventral line, swelling out to reach a maximum width laterally, and then narrowing slightly towards the mid line dorsally (Text-figs. 16–18). This circlet is only comparable with that of *Cnephia strenua* or *C. aurantiacum*; it greatly exceeds that of *A. bancrofti*, which had the widest circlet of previously known species of *Austrosimulium*.

Biology.

Larvae and pupae were found attached to rock in rapids, in clear, cool, fast moving water in company with *Cnephia strenua*. Habits of adults unknown.

Distribution.—Queensland: Head waters of the Massey R., Cape York, November (Wassell); Little Crystal Ck., Mt. Spec Road, 45 m. N. of Townsville, 1,100 ft., November (McMillan, M.J.M.), December (M.J.M.).

INHERITANCE OF REACTION TO WHEAT STEM RUST IN CROSSES INVOLVING MARQUILLO, THATCHER AND HOCHZUCHT.

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[Read 25th May, 1955.]

Synopsis.

The results reported here are part of a programme designed to establish a genic basis for various sources of resistance to wheat stem rust in Australia. These varieties of *Triticum vulgare*, Marquillo, Thatcher and Hochzucht, have been found to have similar genetic backgrounds for resistance to Australian rusts and this resistance in each case is dependent upon multiple factors. It has been further shown that one of these factors, which appears to confer partial resistance, is strongly linked with the locus conditioning resistance in Kenya 744 and Kenya 117A.

The immunity of Thatcher and Hochzucht to race 21 of stem rust is governed by single factors which are allelomorphic and independent of the locus conditioning Kenya resistance.

Introduction.

Triticum durum var. Iumillo has been one of the outstanding sources of stem rust resistance available to wheat breeders. Hayes *et al.* (1920) made a cross between Iumillo and Marquis (*T. vulgare*) with the object of introducing this resistance into commonly cultivated wheats and Marquillo was evolved from this cross. Thatcher was developed subsequently from a cross between a sister line of Marquillo and a Marquis × Kanred selection (Hayes *et al.*, 1936) and it combined the Marquillo type of resistance with Kanred immunity. Both Marquillo and Thatcher are highly resistant to stem rust races prevalent in Australia. Hochzucht is another variety having resistance to rust in this country. The pedigree is not known but it has been mentioned in stem rust tests by Johnson and Newton (1941), Macindoe (1948) and Waterhouse (1952).

A programme designed to establish a genic basis for various sources of resistance was initiated at the University of Sydney and it is the purpose of this paper to report on the findings relating to Marquillo, Thatcher and Hochzucht. The results of a study with Kenya 744 and Kenya 117A have been published earlier (Athwal and Watson, 1954) and the genetic relationship of these Kenya varieties to Marquillo, Thatcher and Hochzucht is discussed here.

Literature Review.

The resistance of Marquillo and Thatcher or the sister line Double Cross has been studied by a number of workers, mostly in the field, but no reference is available on the genetics of resistance shown by Hochzucht. Hayes *et al.* (1925) crossed a Marquis × Iumillo line (a sister selection of Marquillo) which was resistant to a collection of physiologic races in the field, with a Marquis × Kanred selection which had the Kanred immunity to several races in the seedling stage and concluded that the field resistance of the Marquis × Iumillo parent, conditioned mainly by two complementary recessive genes, was inherited independently of the immunity of the Marquis × Kanred parent. Thompson (1925) from a study of the cross Marquis × Iumillo concluded that the resistance of the latter parent was dependent upon more than one factor.

Neatby and Goulden (1930) found that the field resistance of Marquillo in crosses with Marquis × Kanred B_{2-5} was governed by three or more factors, but when Garnet or Reward were used as susceptible parents, many factors appeared to be involved. Double Cross was assumed by these workers to carry two complementary factors for resistance. Neatby (1931, 1933) also obtained results which indicated that Marquillo and Double Cross did not possess any factors affecting the field reaction except those concerned in the seedling reaction in the greenhouse.

Harrington (1931) found a reversal in the genetic ratios when F_3 seedling families of the cross Marquis × Marquillo were tested to race 21 at average temperatures of 69·7° F. and 60·6° F. The results were explained by assuming that Marquis possessed three dominant factors which caused susceptibility at the higher temperature but their action in producing susceptibility was greatly reduced or curtailed at the lower temperatures. The inheritance of rust reaction of Marquillo in the field was explained by Ausemus (1934) on the basis of at least three genetic factors.

Pan (1940) concluded from his studies that Double Cross carried two complementary factors for semi-resistance in the field. Platt *et al.* (1941) made a study of F_3 lines of the crosses Thatcher × S–615–11 and Thatcher × S–633–23 for stem rust reaction in the field. The results from the first cross were explained on the basis of a dominant factor for resistance present in Thatcher and an inhibitor carried by the susceptible variety. In the second cross, however, several factors appeared to be involved as very few resistant lines were obtained. According to Swenson *et al.* (1947) at least two or three recessive genes for resistance to stem rust were involved in differentiating between the resistant reaction of Thatcher and susceptibility of Triunfa in the field. The field resistance of Thatcher was explained by Koo and Ausemus (1951) on the basis of two complementary genes and this variety was also found by these workers to carry an additional factor for high resistance to some races in the seedling stage.

Materials and Methods.

The stem rust resistant varieties of *T. vulgare* used in these studies carry the accession numbers of Sydney University where they have been maintained as single plant selections from the original introductions.

Marquillo 724: Obtained from St. Paul, Minnesota. The spike is awnleted, fusiform, mid-dense; glumes glabrous, white; kernels red, mid-long to long.

Thatcher 1201: Obtained from St. Paul, Minnesota. The spike is awnleted, oblong to fusiform, mid-dense; glumes glabrous, white; kernels red, short.

Hochzucht 1227: Imported from Germany and is very similar to Thatcher in its morphological characters.

Table 1.

Reactions of Marquillo, Thatcher and Hochzucht to Different Races.

Race.	Marquillo.	Thatcher.	Hochzucht.
126	R+	R+ to R	R+ to R
126B	R+	R+ to R	R+ to R
222AB	R+	R+ to R	R+ to R
222BB	R+	R+ to R	R+ to R
15	R− to S	Int. to S	Int. to S
15C	R− to S	Int. to S	Int. to S
21	R+ to SR	I	I
34	R to SR	SR to S	SR to S
38	R to SR	SR to S	SR to S
40	SR to S	S	S
42	SR to S	I	I

The three varieties are resistant both in the glasshouse and in the field to the four common Australian rust races 126, 126B, 222AB, and 222BB. In addition to these races, the range of seedling reaction of these varieties to races 15, 15C, 21, 34, 38, 40 and 42 is recorded in Table 1. The more resistant reaction in each case was obtained at approximately 60–65° F. and the less resistant reaction at approximately 75–80° F. The abbreviated forms of reaction in this table are in accordance with the system of classification discussed below.

Inheritance studies were made using Australian rusts as well as race 21. The mode of inheritance of resistance was determined in the glasshouse by a study of F_1, F_2, F_3 and F_4 generations of crosses of these varieties with susceptible Federation 107.

F_2 populations of crosses involving susceptible varieties other than Federation, as reported under experimental results, were also studied.

Various gradations of reaction between resistance and susceptibility were commonly observed in the F_2 generation and difficulty was encountered in classifying the individual plants. Wherever possible F_2 plants representing different reactions were transplanted in the field and their genotypes were ascertained from their breeding behaviour in the F_3 generation.

It was found by Athwal and Watson (1954) that single factors in Kenya 744 and Kenya 117A responsible for resistance to all the four Australian rusts are allelomorphic and probably identical. The genetic relationship of Marquillo, Thatcher and Hochzucht among themselves, as well as to Kenya 744 and Kenya 117A, was established from a study of the following crosses: Marquillo × Thatcher; Marquillo × Hochzucht; Thatcher × Hochzucht; Marquillo × Kenya 744; Marquillo × Kenya 117A; Thatcher × Kenya 744; Thatcher × Kenya 117A; (Thatcher × Kenya 117A) × Federation; Hochzucht × Kenya 744; Hochzucht × Kenya 117A.

In crosses among resistant varieties sometimes plants with an intermediate type of reaction occurred in the F_2 generation, but their F_2 breeding behaviour indicated that such plants resembled closely other plants classified as semi-resistant. It was therefore considered necessary to study the F_3 generation of such crosses to find the possibility of securing homozygous susceptible lines.

Unless otherwise specified random samples of F_2, F_3 and F_4 populations were employed in all inheritance studies.

As temperature was found to influence the rust reactions, the parents of a cross under study were tested side by side under the same environmental conditions and classification was based on the parental reactions. Where necessary temperature will be defined as low, moderate and high. These conform approximately to temperature ranges of 60–65° F., 67–72° F. and 75–80° F. respectively. Within the limits specified, a range includes an average of minimum and maximum temperatures existing during an infection period. The following classes were used for stem rust reactions in the glasshouse: Immune (I), 0 or 0;— Highly resistant (R+), ;—Resistant (R), ; & 1— Moderately resistant (R–), ;, 1 & 2, 2–, X–, or $3^{=c}$—Semi-resistant (SR), 2, 2+, X or 3^{-c}— Intermediate (Int), 3^{c} or 3^{+c}—Susceptible (S), 3 & 4—Segregating (Seg), F_3 or F_4 lines segregating for resistant and susceptible individuals.

If hybrid lines showed gradations of reactions, they were defined by an appropriate range as, for example, R+ to R, R+ to SR, etc.

Experimental Results.

As Kanred is susceptible to races 126, 126B, 222AB, and 222BB, it is understood that both Marquillo and Thatcher inherit their resistance to stem rusts from *Triticum durum* var. Iumillo. The parentage of Hochzucht is not known, but the present investigations have shown that the reaction of this variety to race 222AB appears to be inherited in a manner very similar to that of Marquillo and Thatcher. The results from inheritance studies with these varieties will, therefore, be discussed together.

As indicated in Table 1, Marquillo was highly resistant (R+) to races 126, 126B, 222AB and 222BB at low (60–65° F.) as well as at high temperatures (75–80° F.). Thatcher and Hochzucht each showed a slight range from (R+) to (R), but there was little difference between the reactions of these varieties at low and high temperatures because the (R) type of resistance produced at high temperatures was always characterized by a predominance of the fleck over the 1 type of reaction. It was, however, observed that temperature had a significant effect on the type of segregation in crosses of a susceptible variety with each of the three resistant parents. Segregates equalling or approaching the resistance of parent varieties were obtained more easily at lower temperatures than at higher temperatures and some F_3 lines appeared to be resistant at the former but susceptible at the latter temperatures.

It is quite common that a variety shows less resistance at higher temperatures, but F_2 or F_3 segregation ratios of its crosses with a susceptible variety will essentially

remain unchanged if the classification is based on the parental reaction. This fact, however, did not apply to inheritance studies with Marquillo, Thatcher and Hochzucht, and in view of these complications, temperatures prevailing during the tests will be defined as low, moderate and high. Most of the glasshouse work was done within a range of 67–72° F. and where no reference is made to temperature it will be understood that the data have been obtained at moderate temperatures.

TABLE 2.

Reactions of Marquillo, Thatcher and Hochzucht to Races 222AB and 21 at Low, Moderate and High Temperatures.

Variety.	Race.	Reactions at Different Temperatures.		
		Low.	Moderate.	High.
Marquillo	222AB	R+	R+	R+
	21	R+	R to R−	SR
Thatcher	222AB	R+	R+	R
	21	I	I	I
Hochzucht	222AB	R+	R+	R
	21	I	I	I

Marquillo, Thatcher and Hochzucht were particularly susceptible to light intensity and a poor light resulted in a high degree of chlorosis on the leaves, especially around the infection spots in crosses involving these varieties. As there were no arrangements to regulate light and temperature, the above-mentioned definition of temperature will indicate only broadly the effect of temperature on segregation ratios.

TABLE 3.

F_2 Reactions at Low, Moderate and High Temperatures of Crosses Between Susceptible Varieties Federation 107 (S), Kanred 4 (S), Mentana 1124 (Int. to S) and Hofed 1200 (S) and the Resistant Varieties Marquillo, Thatcher and Hochzucht.

Temperature.	Cross.	F_2 Reactions.				
		Resistant.		Semi-Resistant. (R− and SR.)	Susceptible. (Int. and S.)	Total.
		(R+.)	(R.)			
Low	Federation × Marquillo ..	61	78	192	202	533
,,	Marquillo × Hofed ..	97	77	291	309	774
,,	Mentana × Thatcher	63	89	333	136	621
,,	Federation × Hochzucht ..	61	79	288	233	661
Moderate	Federation × Marquillo ..	28	124	346	393	891
,,	Kanred × Marquillo	32	111	342	328	813
,,	Mentana × Marquillo ..	22	103	366	173	664
,,	Federation × Thatcher ..	10	37	138	141	326
,,	Thatcher × Hofed	25	71	289	222	607
,,	Federation × Hochzucht ..	14	45	297	267	623
High	Federation × Marquillo ..	—	17* —	50	202	269
,,	Federation × Thatcher ..	—	7 —	56	328	391
,,	Federation × Hochzucht ..	—	16 —	99	276	391

* In this and the subsequent tables, the numbers recorded between two categories of reaction show that the two classes are grouped together.

Races 222AB and 21 were used for inheritance studies in the glasshouse. As it will not be convenient to show the reactions of Marquillo, Thatcher and Hochzucht in each table, their reactions at low, moderate and high temperatures are recorded in Table 2 for reference where necessary.

Studies with race 222AB.—Susceptibility was dominant in the F_1 generation of crosses between Federation and each of the resistant varieties Marquillo, Thatcher and Hochzucht. Types of F_2 segregation obtained at different temperatures in crosses involving the resistant varieties are shown in Table 3.

In the F_2 generation of all crosses, a complete gradation of reactions between high resistance and full susceptibility was observed, and the mode of inheritance of rust reaction appeared highly complex. Originally the reactions were recorded under six different classes, but quite often plants occurred which could not be clearly defined. As temperature and light conditions play an important part in the development of a particular type of infection, the classification was necessarily arbitrary and it was considered more appropriate to report the data under four classes as shown in Table 3. Considering the highly resistant type of reaction shown by the resistant parents, the plants with an intermediate type of reaction have been grouped with the susceptible class and the (R– and SR) class represents a reaction intermediate between the susceptible and resistant parents.

Mentana was used as the susceptible parent in certain crosses reported in Table 3, but this variety, unlike Federation, is not fully susceptible. The crosses involving Mentana show a deficiency of susceptible plants and an excess of semi-resistant plants: there is, however, no appreciable change in the proportion of fully resistant plants. It appears that the gene or genes responsible for the moderately susceptible reaction of Mentana in conjunction with certain minor genes in the resistant varieties have caused an increase in the proportion of semi-resistant plants with a corresponding reduction in the proportion of susceptible plants.

TABLE 4.

The F_3 Breeding Behaviour at Moderate Temperatures of F_2 Plants of the Cross Federation × Marquillo Representing Different Reaction Types at the Same Temperatures.

F_2 Reactions.	F_3 Reactions.							
	R+	R+ to R R+ to R–	R+ to SR R to SR	R– to SR	R+ to S R to S	R– to S SR to S	S	Total
R+ and R ..	–	22	25	1	2	–	–	50
R– and SR ..	–	2	12	2	9	1	–	26
Int. and S ..	–	–	1	1	64	12	31	109
Total	–	24	38	4	75	13	31	185

Goulden (1930) found that the proportion of resistant plants in the field in crosses between susceptible varieties and Marquillo varied with the susceptible variety used in crosses, but the data in Table 3 do not show any significant variation in the percentage of resistant plants in crosses of this variety with the susceptible parents used here. Slight differences which occur especially at high temperatures in crosses between susceptible varieties and Marquillo, Thatcher and Hochzucht more or less disappear at low temperatures. In addition to minor differences in the genetic constitution of the resistant varieties, the observed variations are likely to occur due to light conditions and minor changes in the temperature.

F_2 plants of the crosses Federation × Marquillo, Federation × Thatcher and Federation × Hochzucht, which had been tested in the glasshouse with race 222AB, were transplanted in the field. The F_3 breeding behaviour of these plants was found against the same race of rust and comparisons of F_2 and F_3 reactions are given in Tables 4, 5 and 6. All the F_3 tests were carried out at moderate temperatures, but only the Federation × Marquillo F_2s had been tested at these temperatures; the F_2s of Federation × Thatcher and Federation × Hochzucht crosses were tested at high temperatures.

The segregating lines in all the three crosses in Tables 4, 5 and 6 did not behave according to any definite pattern, and all sorts of aberrant ratios were indicated. There were lines which showed preponderance of susceptible plants, and there were others in which resistant or semi-resistant plants predominated. There were even lines which

contained only one or two resistant or semi-resistant individuals in an average family size of about 20 or 25 plants. It is quite likely that some of the lines which were actually segregating F_3 lines of crosses involving Marquillo, suggested that these may be due to abnormal chromosome behaviour. The cytological studies made by Powers (1932) and Love (1941) show that Marquillo is germinally unstable.

TABLE 5.

The F_3 Breeding Behaviour at Moderate Temperatures of F_2 Plants of the Cross Federation × Thatcher Tested at High Temperatures.

F_2 Reactions.	F_3 Reactions.							
	R+	R+ to R	R+ to SR R to SR	R− to SR	R+ to S R to S	R− to S SR to S	S	Total
R+ and R ..	—	4	—	—	—	—	—	4
R− and SR ..	—	4	19	2	1	—	—	26
Int. and S ..	—	—	7	11	41	7	6	72
Total	—	8	26	13	42	7	6	102

In crosses of Marquillo, Thatcher and Hochzucht with Federation, one important aim was to find lines showing the parental reactions. The results in the preceding tables show that not one F_3 line homozygous for the (R+) type of reaction was recovered in any of the three crosses. The reaction of F_1 plants had shown that resistance was recessive, and in the F_2 generation plants were obtained which were highly resistant like the parents, but the F_3 breeding behaviour of these plants shows that they did not breed true.

TABLE 6.

The F_3 Breeding Behaviour at Moderate Temperatures of F_2 Plants of the Cross Federation × Hochzucht Tested at High Temperatures.

F_2 Reactions.	F_3 Reactions.							
	R+	R+ to R	R+ to SR R to SR	R− to SR	R+ to S R to S	R− to S SR to S	S	Total
R+ and R ..	—	3	1	—	—	—	—	4
R− and SR ..	—	1	19	10	2	2	—	34
Int. and S ..	—	—	5	21	22	28	16	92
Total	—	4	25	31	24	30	16	130

The comparison of F_2 and F_3 reactions at moderate temperatures of the cross Federation × Marquillo shows that most of the resistant plants gave progenies possessing various grades of resistance, and the susceptible plants gave either segregating or susceptible progenies. As it was not possible to provide exactly the same conditions during F_2 and F_3 tests, the minor discrepancies can be expected on the basis of environmental differences. The comparison of F_2 reactions (at high temperatures) and F_3 reactions (moderate temperatures) of the crosses Federation × Thatcher and Federation × Hochzucht reveal more clearly the influence of temperature. Some of the susceptible F_2 plants in both of these crosses gave progenies with various grades of resistance. Almost all the resistant plants gave resistant or partially resistant progenies. A line was actually isolated from the cross Federation × Thatcher, which was homozygous for high resistance at low temperatures, moderate resistance at moderate temperatures and moderate susceptibility at high temperatures.

Seed was available in 105 of the 185 F_3 lines of the cross Federation × Marquillo tested at moderate temperatures (Table 4). These 105 lines were tested against the same race of rust at high temperatures, and the results are compared in Table 7.

Table 7 shows that some of the F_3 lines which were resistant (R+ to R) at moderate temperatures showed segregation at high temperatures (R+ to S or R to S), whilst some of the segregating lines were found to be homozygous susceptible at higher temperatures. A difference in the reaction of F_3 families of a cross between Marquis

TABLE 7.

Comparison of Reactions of 105 F_3 Lines of the Cross Federation × Marquillo at Two Different Temperatures.

Reactions at Moderate Temperatures.	Reactions at High Temperatures.						
	R+ to R	R+ to SR R to SR	R− to SR	R+ to S R to S	R− to S SR to S	S	Total.
R+ to R or R+ to R− ..	2	10	—	7	—	—	19
R+ to SR or R to SR ..	—	14	1	7	1	—	23
R+ to S or R to S ..	—	—	—	18	10	11	39
R− to S or SR to S ..	—	—	—	—	2	3	5
S	—	—	—	—	—	19	19
Total	2	24	1	32	13	33	105

and Marquillo was also observed by Harrington (1931) when tests were made with race 21 at average temperatures of approximately 61° and 70° F. As in the cross Federation × Thatcher, a pure breeding line was isolated from the Federation × Marquillo cross, which showed high resistance to race 222AB at low temperatures, moderate resistance at moderate temperatures and susceptibility at high temperatures. A cross was made between Federation and this line (49.258) to study the mode of inheritance of rust reaction. F_2 data from this cross at low and moderate temperatures are given in Table 8.

TABLE 8.

F_2 Reactions of the Cross Federation × 49·258 against Race 222AB at Moderate and Low Temperatures.

Temperature.	Parents or Cross.	F_2 Reactions.						
		(R+)	(R)	(R−)	(SR)	(Int.)	(S)	Total
Moderate	Parents	—	—	49·258	—	—	Federation	—
,,	Federation × 49·258	—	—	15	22	3	150	190
Low	Parents	49·258	—	—	—	—	Federation	—
	Federation × 49·258	8	30	— 87	—	84	306	515

The results in Table 8 show that even the reaction of the line 49.258 which possesses only part of the resistance complement carried by Marquillo is not simply inherited. At moderate as well as at low temperatures approximately 1/16 of the F_2 plants either equal or approach the reaction of the resistant line and therefore at least two main factors must be assumed to govern the resistant reaction. From these results it can also be inferred that the resistance of Marquillo, Thatcher or Hochzucht must be dependent on several genes and that the action of some of these genes is susceptible to temperature effects.

Random samples of F_3 and F_4 lines of crosses between Federation and each of the resistant varieties were tested against race 222AB at different times during the course of this study, and the results are summarized in Table 9.

The results in Table 9 again show that not one line was pure breeding for the resistant reaction of the parents; there were, however, lines under the class (R+ to R) which closely approached their reaction. Even at high temperatures one out of 91 F_3 lines of the cross Federation × Marquillo belonged to the (R+ to R) class, and this

TABLE 9.

Reactions of F_3 and F_4 Lines of Crosses between Federation and Marquillo, Thatcher and Hochzucht.

Temperature.	Cross.	Reactions.						
		R+	R+ to R	R+ to SR R to SR R− to SR	R+ to S R to S	R− to S SR to S	S	Total
High	Federation × Marquillo F_3s	−	1	15	30	23	22	91
Moderate	,, ,, F_4s	−	3	44	41	50	11	149
High	Federation × Thatcher F_3s	−	−	7	10	51	41	109
Moderate	,, ,, F_3s	−	1	42	19	87	30	179
,,	,, ,, F_4s	−	3	51	61	78	18	211
,,	Federation × Hochzucht F_3s	−	−	50	50	84	26	210
,,	,, ,, F_4s	−	1	37	46	28	14	126

line, though not as resistant as Marquillo, equals the reaction of Thatcher or Hochzucht at that temperature (Table 3). None of the 109 F_3 lines of the cross Federation × Thatcher falls under the class (R+ to R) at high temperatures. The results show that with the rise of temperature there is an increase in the numbers of susceptible lines, and this is accompanied by a reduction in the numbers of resistant lines. The 149 F_4 lines of the cross Federation × Marquillo, and 211 F_4 lines of the cross Federation × Thatcher in Table 9 were tested against race 222AB at low temperatures, and the reactions of these lines at two different temperatures are compared in Tables 10 and 11.

TABLE 10.

Comparison of the Reactions of Federation × Marquillo F_4 Lines at Moderate and Low Temperatures.

Reactions at Moderate Temperatures.	Reactions at Low Temperatures.							
	R+	R+ to R	R+ to SR R to SR	R− to SR	R+ to S R to S	R− to S SR to S	S	Total
R+	−	−	−	−	−	−	−	−
R+ to R ..	2	1	−	−	−	−	−	3
R+ to SR or R to SR ..	9	3	15	−	(2)	−	−	29
R− to SR ..	1	3	9	2	−	−	−	15
R+ to S or R to S	−	6	8	−	26	(1)	−	41
R− to S or SR to S	2	1	11	−	23	13	−	50
S	−	−	1	−	2	3	5	11
Total	14	14	44	2	53	17	5	149

Of the F_4 lines of the cross Federation × Marquillo tested at low temperatures (Table 10), 14 were as resistant as Marquillo and another 14 approached this reaction. Though most of these 28 lines showed various grades of resistance at moderate temperatures, some even showed segregation for susceptible individuals. These 28 lines are apparently drawn from all different classes except the susceptible one. Of the 11 lines which were susceptible at moderate temperatures, however, only 5 were susceptible at low temperatures; others showed various grades of resistance or segregation for resistance and susceptibility. These results demonstrate that lines homozygous for high resistance can be obtained more easily at low temperatures.

The 211 F_4 lines of the cross Federation × Thatcher whose reactions at low and moderate temperatures are recorded in Table 11, show a behaviour similar to the Federation × Marquillo cross. The proportion of lines equalling or approaching the reaction of Thatcher at low temperatures is, however, comparatively lower, only 6 lines were classified as (R+) and another 9 lines as (R+ to R).

Tables 10 and 11 show that quite a large number of lines belonged to the same class at the two different temperatures, but in most of these lines a less resistant or a susceptible reaction predominated at lower temperatures. Such differences are not revealed by these tables. A few lines in Tables 10 and 11 recorded in parentheses showed unexpected behaviour, but considering the method of classification and occurrence of abnormal segregation ratios, it should be regarded as a minor discrepancy. It is, however, quite clear from the data in these tables that at the lower temperatures there is a comparatively greater percentage of those lines which approach or equal the reaction of the resistant parent and a smaller percentage of those lines which equal the reaction of the susceptible parent.

TABLE 11.

Comparison of the Reactions of Federation × Thatcher F_4 Lines at Moderate and Low Temperatures.

Reactions at Moderate Temperatures.	Reactions at Low Temperatures.							
	R+	R+ to R	R+ to SR R to SR	R− to SR	R+ to S R to S	R− to S SR to S	S	Total
R+	—	—	—	—	—	—	—	—
R+ to R ..	1	1	(1)	—	—	—	—	3
R+ to SR or R to SR ..	3	5	20	(1)	(1)	—	—	30
R− to SR ..	—	1	9	10	(1)	—	—	21
R+ to S or R to S	2	1	17	1	38	(2)	—	61
R− to S or SR to S	—	1	15	1	25	36	—	78
S	—	—	1	—	2	12	3	18
Total	6	9	63	13	67	50	3	211

Hayes *et al.* (1925) and others who studied the inheritance of Marquillo or Thatcher resistance in the field, concluded that the two or three factors responsible for resistance were complementary in action, but the glasshouse studies reported here show that at least one of the resistance factors has an individual effect of its own which is comparatively weaker and may be susceptible to temperature effect. An examination of Table 8 will show that approximately one-fourth of the total number of plants of the cross Federation × 49·258 tested at low temperatures possess various grades of resistance, and it therefore appears that of the two factors assumed to control the rust reaction, one has some individual effect, and the other gene is strictly of a complementary or modifying nature. Similarly F_3 or F_4 data in crosses of Federation with each of the resistant varieties Marquillo, Thatcher or Hochzucht show that at moderate temperatures approximately 25% or more of the lines show various grades of resistance. Probably the weak effect of a gene is not noticeable in the field. The line 49·258, which was isolated from the cross Federation × Marquillo and which shows a reaction ranging from high resistance at low temperatures to susceptibility at high temperatures, was found to be susceptible in the field where four races of Australian stem rust were prevalent and where Marquillo maintained its high resistance.

It should be emphasized that some of the Federation × Marquillo F_4 lines which appear to be as resistant as Marquillo at low temperatures cannot be regarded as identical with the latter, because such lines do not maintain their high resistance at higher temperatures. So far, out of the few hundred F_3 or F_4 lines of this cross tested at moderate or high temperatures, not a single line bred true for the parental resistance.

In a sample of over 1,000 lines of the cross Garnet × Marquillo, Neatby and Goulden (1930) did not find one line equal to Marquillo in field resistance.

The results reported earlier indicate that it is easier to recover a resistant line of the (R+ to R) type from the cross Federation × Marquillo than from the crosses Federation × Thatcher and Federation × Hochzucht. Table 1 shows that Thatcher and Hochzucht give parallel reactions against all the races, and that these two varieties do not possess as high resistance as Marquillo against a number of races. It appears that these two varieties do not inherit all the resistance genes of Marquillo.

The results on the inheritance of the Marquillo, Thatcher or Hochzucht resistance must be interpreted on a multiple factor basis, some are major factors, whilst others are minor factors which intensify the effect of major genes. Only when all the major and minor genes are present together could a hybrid line maintain the parental reaction at all temperatures. If minor factors for resistance behave as dominant, it will also explain why the resistant F_2 plants do not breed true to their type. It also appears that at least one of the major factors has some individual effect, and one or more factors are susceptible to temperature.

Race Relationship: The reactions of 149 F_4 lines of the Federation × Marquillo cross and 126 F_4 lines of the Federation × Hochzucht cross to race 222AB are recorded in Table 9. These lines gave approximately the same reactions against races 126 and 222BB. Of the 211 F_4 lines of the cross Federation × Thatcher, whose reactions to race 222AB are also given in Table 9, 167 were tested against races 126 and 222BB, and the results showed that these lines behaved in a similar manner against races 222AB, 126 and 222BB. It can be concluded from these studies that the same group of genes in Marquillo, Thatcher or Hochzucht condition resistance to races 222AB, 126 and 222BB.

As shown in Table 2, Marquillo gave a resistant or moderately resistant type of reaction to race 21 at moderate temperatures. The relationship between races 222AB and 21 was also determined by a study of 149 F_4 lines of the cross Federation × Marquillo. A comparison of reactions against the two races showed that all lines which possessed various grades of resistance against race 222AB, showed a comparatively less resistant reaction to race 21; lines susceptible to one race were also susceptible to the other. It appears, therefore, that most of the genes in Marquillo which control its high resistance to race 222AB are responsible for its resistant or moderately resistant reaction against race 21. The line 49·258 selected from the cross Federation × Marquillo was found to be semi-resistant to race 21 at moderate temperatures and susceptible at high temperatures.

Studies with race 21: Thatcher and Hochzucht were immune to race 21. Thatcher inherited its immunity from Kanred which was found by Aamodt (1922) to be dependent on a single dominant factor. Hayes *et al.* (1925) reported that the field resistance of Thatcher derived from Iumillo was inherited independently of the immunity factor.

The inheritance of rust reaction to race 21 was studied in the crosses Federation × Thatcher and Federation × Hochzucht. F_1 seedlings of each of these two crosses were immune to this race. The reactions of F_2 plants at high and low temperatures are given in Table 12, which also includes reactions of 83 F_3 lines of the cross Federation × Hochzucht at high temperatures.

The F_2 data at high temperatures on crosses between Federation and each of the immune parents Thatcher and Hochzucht agree with a 3:1 ratio ($P > 0{\cdot}50$). The reactions were clear-cut and the F_2 segregates were either immune or susceptible. The F_2 data on the same crosses at low temperatures, however, indicate the presence in these varieties of another set of factors for resistance to race 21. If all the plants which are not immune (resistant and susceptible plants) are grouped together the observed data on the crosses Federation × Thatcher and Federation × Hochzucht in Table 12 agree with a 3:1 ratio; the P value respectively lies between 0·10 and 0·20, and 0·30 and 0·50.

The results on 83 F_3 lines of the cross Federation × Hochzucht obtained at high temperatures (Table 12) show that 4 lines gave a reaction ranging from semi-resistance to susceptibility, the rest of the lines were either immune, segregating or susceptible. As

semi-resistant reaction does not appear to bear any relationship with the immune reaction, these 4 lines should be combined with the susceptible class. These data agree with a 1:2:1 ratio (P = 0·30–0·50) as expected on the basis of a single factor for immunity.

The breeding behaviour of 105 F_2 plants of the cross Federation × Thatcher, which had been previously tested with race 21 at high temperatures, was determined under similar temperature conditions, and the F_2 and F_3 results are compared in Table 13.

The F_2 plants showing immune type of reaction to race 21 were indistinguishable from the ones which might have escaped infection. Table 13 shows that one of the 79

TABLE 12.

Reactions of Federation × Thatcher F_2 Plants and Federation × Hochzucht F_2 Plants and F_3 Lines against Race 21.

Temperature.	Cross and Generation.	Reactions to Race 21.						
		Immune.	Resistant.		Segregating.		Susceptible.	Total.
			(R)	(SR)	(I to S)	(SR to S)		
High	Federation × Hochzucht F_2	198	—	—	—	—	62	260
,,	,, ,, F_3	16	—	—	41	4	22	83
,,	Federation × Thatcher F_2	132	—	—	—	—	41	173
Low	Federation × Hochzucht F_2	439	6	36	—	—	81	562
,,	Federation × Thatcher F_3	376	4	47	—	—	88	515

plants recorded as immune gave homozygous susceptible progeny. Apparently this plant escaped infection in the F_2 tests. The rest of the immune plants, as expected, gave homozygous immune or segregating progenies. All the susceptible plants except one bred true. The F_3 family from this exceptional susceptible plant showed a range of reaction from semi-resistance to susceptibility. As in the cross Federation × Hochzucht the F_3 data on the Federation × Thatcher cross also agrees with a 1:2:1 ratio (P = 0·95).

TABLE 13.

The F_3 Breeding Behaviour of Federation × Thatcher F_2 Plants Representing the Immune and Susceptible Reactions.

F_2 Classification.	F_3 Breeding Behaviour.				
	Immune.	Segregating.		Susceptible.	Total.
		(I to S)	(SR to S)		
Immune	27	51	—	1	79
Susceptible	—	—	1	25	26
Total ..	27	51	1	26	105

The F_2 data at low temperatures in Table 12 indicate that both Thatcher and Hochzucht have an additional set of factors for resistance which is completely hypostatic to the immunity factor. It appears, however, that the action of this set of factors is greatly influenced by temperature as there was very little evidence from the F_2 and F_3 data at high temperatures (Tables 12 and 13) for the presence in these varieties of any resistance factor against race 21 except the one controlling immunity.

Thatcher and Hochzucht were immune to race 21 throughout these experiments. As the immunity factor is epistatic, then reactions do not reveal anything about the influence of temperature on the action of a set of factors for resistance present in these

varieties. Marquillo was semi-resistant to race 21 at high temperatures, but was highly resistant to the same race at low temperatures (Table 2). It has been found that the same genes in Marquillo which control its high resistance to race 222AB are mainly responsible for the resistance of this variety to race 21. As Thatcher and Hochzucht do not incorporate all the genes for resistance possessed by Marquillo, it is probable that the resistance conferred by the additional set of factors in the former two varieties against race 21 will not be as effective as that of Marquillo. This is apparent from the reaction of Celebration 1374 against race 21. Celebration was developed from the cross Double Cross × Dundee × Dundee (*Agr. Gazette N.S.W.*, 1946), Double Cross being a sister line to the variety Thatcher. Dundee is susceptible to races 222AB and 21.

TABLE 14.

Distribution of Federation × Thatcher and Federation × Hochzucht F_4 Lines for Their Reactions to Races 222AB and 21.

Cross.	Reaction to Race 222AB.	Reaction to Race 21.						
		I	I to SR	I to S	R− to S SR to S	R− to SR R− to Int.	S	Total.
Federation × Thatcher	R+ to R or R+ to SR or R to SR	6	8	7	3	3	—	27
	R− to SR ..	2	1	1	—	5	—	9
	S	2	—	8	—	—	3	13
Total ..	.. ..	10	9	16	3	8	3	49
Federation × Hochzucht	R+ to R or R+ to SR or R to SR	7	7	7	2	6	—	29
	R− to SR ..	3	5	5	—	1	—	14
	S	4	—	7	—	—	3	14
Total ..	.. ..	14	12	19	2	7	3	57

Celebration does not inherit the immunity factor, but it is nearly as resistant as Thatcher to race 222AB. Tests with race 21 showed that this variety was moderately susceptible at high temperatures, and gave a resistant reaction at moderate temperatures. Evidently Celebration and probably Thatcher and Hochzucht do not possess all of the resistance genes which confer a semi-resistant reaction on Marquillo against race 21 at high temperatures.

F_4 lines of the crosses Federation × Thatcher and Federation × Hochzucht which were either susceptible or showed various grades of resistance against race 222AB at moderate temperatures were tested against race 21 at the same temperatures. Table 14 presents a comparison of reaction against the two races.

The data in Table 14, though not very extensive, are quite revealing. The results show that the immunity of Thatcher and Hochzucht to race 21 is inherited independently of their resistance to race 222AB. Some of the F_4 lines which were susceptible to race 222AB are homozygous immune to race 21. It is also apparent from the preceding table that there are other genes both in Thatcher and Hochzucht producing a moderately resistant or semi-resistant reaction against race 21, as lines were obtained breeding pure for this reaction. Probably these genes would give higher resistance at low temperatures. As in the case of Marquillo, these genes in Thatcher and Hochzucht for partial resistance to race 21 appear to belong to the same group of genes upon which depends the resistance of each of these varieties to race 222AB.

Genetic Relationship between Marquillo, Thatcher and Hochzucht.—Data on F_1, F_2 and F_3 generations of diallel crosses among the three varieties are presented in Table 15.

Marquillo × *Thatcher.*—The F_1 seedlings of this cross were highly resistant to race 222AB. As the resistance of the two parents in crosses with Federation was recessive, the results indicate that the same loci in Marquillo and Thatcher condition resistance. No susceptible segregate was observed in the F_2 and F_3 populations of this cross, and these results confirm the indications obtained from the behaviour of F_1 plants.

It will be observed from the table that of the 943 F_2 plants of the cross of Thatcher × Marquillo two were not as highly resistant as Marquillo. The occurrence of such plants can probably be explained on the basis of germinal instability of Marquillo (Love, 1941) as plants showing lower resistance have sometimes been found even in the parent lines. It is also possible that the occurrence of less resistant plants may be due

TABLE 15.

F_1, F_2 and F_3 Reactions of Diallel Crosses among Marquillo, Thatcher and Hochzucht against Races 222AB and 21.

Cross and Generation.	Race.	Reactions.					
		Immune.	Resistant.			Susceptible.	Total.
			(R+)	(R)	(R−)		
Marquillo × Thatcher F_1 ..	222AB	—	6	—	—	—	6
,, ,, F_1 ..	21	5	—	—	—	—	5
,, ,, F_2 ..	222AB	—	941	—	2	—	943
,, ,, F_2 ..	21	635	—	—	180	—	1 (Int.) 816
,, ,, F_3 ..	222AB	—	166	—	—	—	166
Marquillo × Hochzucht F_1 ..	222AB	—	6	—	—	—	6
,, ,, F_1 ..	21	6	—	—	—	—	6
,, ,, F_2 ..	222AB	—	747	—	7	—	754
Thatcher × Hochzucht F_1 ..	222AB	—	6	—	—	—	6
,, ,, F_1 ..	21	8	—	—	—	—	8
,, ,, F_2 ..	222AB	—	936	—	21	—	957
,, ,, F_2 ..	21	1480	—	—	—	—	1480
,, ,, F_3 ..	222AB	—	145	—	—	—	145
,, ,, F_3 ..	21	123	—	—	—	—	123

to the difference among the two varieties in minor genes controlling rust reaction. Single plants showing less resistance were also encountered in a few F_3 families, but as all the other plants in such families were showing high resistance, these were classed as highly resistant (R+).

It was earlier concluded that the same genes in Marquillo, and probably Thatcher, which confer resistance against race 222AB were also operating against race 21. These genes are, however, not as effective in producing resistance against race 21 as they are against race 222AB. There was evidence that the genes for resistance in Thatcher, in the absence of the immunity factor, can produce a moderately resistant reaction against race 21 at moderate temperatures. These genes will probably show high resistance to this race at low temperatures. It can, therefore, be inferred that no susceptible plant should be obtained in the cross Marquillo × Thatcher at least at low temperatures when tested against race 21, and approximately three-quarters of the F_2 plants should be immune.

257 F_2 plants of the cross Marquillo × Thatcher were tested with race 21. The results were obtained at low temperatures, and are not included in the table. 199 plants were immune and 58 showed a highly resistant reaction, and the agreement of the observed data to a 3:1 ratio is satisfactory (P = 0·30–0·50). Another sample of 816 plants whose reactions are recorded in Table 15 (635 I, 180 R to R–, 1 Int.) was tested at moderate temperatures. The immune and non-immune plants agree with a 3:1 ratio with a P value of only 0·05–0·10. The poor agreement is due to the excess of immune plants which probably include some escapes. A plant giving an intermediate type of reaction also

occurred in the F_2 population, and it would probably be possible to get even susceptible plants at high temperatures.

It can be concluded that the major genes for resistance to races 222AB and 21 in Marquillo and Thatcher are allelomorphic and the factor for immunity against race 21 present in Thatcher is inherited independently of the genes giving resistance.

Thatcher × Hochzucht.—Against race 222AB, this cross showed the same behaviour as the Marquillo × Thatcher cross. As indicated in Table 15, F_1 plants were highly resistant and no susceptible segregate was obtained in the F_2 and F_3 generations. The tests carried out with race 21 showed that all the F_2 plants and F_3 lines were immune. It appears that Thatcher and Hochzucht have similar genetic backgrounds, both for high resistance to race 222AB and for immunity to race 21.

Marquillo × Hochzucht.—As expected, the results in Table 15 show that most of the genes for resistance in Marquillo and Hochzucht are at the same loci.

Relationship of Marquillo, Thatcher and Hochzucht to Kenya 744 and Kenya 117A 1347.—It has been shown (Athwal and Watson, 1954) that the seedling resistance of Kenya 744 and Kenya 117A to four Australian rusts is dependent upon single factors which are allelomorphic and probably identical. These two varieties are also resistant to race 21 and further work has revealed that the same factor both in Kenya 744 and Kenya 117A confers resistance against races 222AB and 21. The reactions of a selected sample of 102 F_3 lines of the cross Federation × Kenya 744 (43 Resistant, 40 susceptible, 19 segregating) and 70 F_4 lines of the cross Federation × Kenya 117A (30 Resistant, 25 susceptible, 15 segregating) were found to be the same against these two races. As expected, no plant susceptible to race 21 was observed in an F_2 population of 665 individuals of the cross Kenya 744 × Kenya 117A.

The present studies indicate that major genes for high resistance to race 222AB in Marquillo, Thatcher and Hochzucht are allelomorphic and that most of these are also responsible for a less resistant reaction against race 21. The results also show that the immunity of Thatcher and Hochzucht to race 21 is conditioned at the same locus. For the sake of convenience, the major genes for resistance in Marquillo, Thatcher and Hochzucht will be referred to as the resistance factors and a single factor for immunity in the latter two varieties as the immunity factor. It was the purpose of the following studies to examine the relationship of the locus conditioning Kenya resistance against races 222AB and 21 to the resistance genes and the immunity factor. The following crosses were studied: Marquillo × Kenya 744; Marquillo × Kenya 117A; Thatcher × Kenya 744; Thatcher × Kenya 117A; Hochzucht × Kenya 744; Hochzucht × Kenya 117A.

On the basis of previous results these six crosses should show the same behaviour against race 222AB and the required information could have been obtained by a study of any one cross. As the crosses had, however, been made in the absence of present knowledge and the material was available, it was considered appropriate to collect data on all of them.

The reaction of Kenya varieties to races 222AB and 21 was R–. For the reactions of other parents see Table 2 (Moderate temperatures).

The data in Table 16 show that, excepting one plant in the cross Marquillo × Kenya 744 which appeared to be susceptible, no other segregate susceptible to race 222AB was obtained in an F_2 population of several hundred plants of these crosses. This single susceptible plant was transplanted in the field, and its F_3 progeny, when tested with the same race of rust, gave a reaction ranging from a semi-resistant to intermediate type. The F_3 breeding behaviour of a sample representing the small proportion of F_2 plants with intermediate type of reaction observed in these crosses proved that genotypically they resembled closely semi-resistant F_2 plants. The F_3 data in Table 17 show that these crosses do not yield any segregating or susceptible line. It appears, therefore, that the locus conditioning Kenya resistance is strongly linked with one of the major genes in Marquillo, Thatcher or Hochzucht. This major gene is apparently capable of producing at least a semi-resistant reaction when present alone, and this fact has already been indicated in the inheritance studies with these varieties.

The reactions of F_1 seedlings of crosses of Kenya varieties with Thatcher and Hochzucht against race 21 (Table 16) show that immunity is epistatic to the Kenya resistance. Of the 819 F_2 plants of the cross Thatcher × Kenya 117A tested against the same race, 622 were immune, 196 R– and SR and 1 Intermediate. The observed frequency of the immune and non-immune plants agree with a 3:1 ratio (P = 0·50–0·70).

TABLE 16.

Reactions to Race 222AB and 21 of F_1 and F_2 Populations of Crosses of Kenya Varieties with Marquillo, Thatcher and Hochzucht.

Cross and Generation.	Race.	Reactions.					
		Immune.	Resistant. (R+) and (R)	Resistant. (R−) and (SR)	Intermediate.	Susceptible.	Total.
Marquillo × Kenya 744 F_1 ..	222AB	—	—	14	—	—	14
,, ,, ,, F_2 ..	222AB	—	322	983	15	1	1321
Marquillo × Kenya 117A F_1 ..	222AB	—	—	11	—	—	11
,, ,, ,, F_2 ..	222AB	—	— 821	—	11	—	832
Thatcher × Kenya 744 F_1 ..	222AB	—	—	7	—	—	7
,, ,, ,, F_1 ..	21	8	—	—	—	—	8
,, ,, ,, F_2 ..	222AB	—	251	— 788	—	—	1039
Thatcher × Kenya 117A F_1 ..	222AB	—	—	3	—	—	3
,, ,, ,, F_1 ..	21	5	—	—	—	—	5
,, ,, ,, F_2 ..	222AB	—	74	250	1	—	325
,, ,, ,, F_2 ..	21	622	—	196	1	—	819
Hochzucht × Kenya 744 F_1 ..	222AB	—	—	4	—	—	4
,, ,, ,, F_1 ..	21	4	—	—	—	—	4
,, ,, ,, F_2 ..	222AB	—	153	519	3	—	675
Hochzucht × Kenya 117A F_1	222AB	—	—	2	—	—	2
,, ,, ,, F_1	21	4	—	—	—	—	4
,, ,, ,, F_2	222AB	—	77	409	—	—	486

As the resistance factors in Thatcher and Hochzucht against race 222AB appear to be also operative against race 21 at the moderate temperatures prevailing during this test, no fully susceptible segregate is normally expected. 118 F_2 families of the three-way cross (Thatcher × Kenya 117A) × Federation were also tested against race 21. The

TABLE 17.

Reactions to Race 222AB of F_3 Lines of Crosses of Kenya Varieties with Marquillo and Thatcher. (Reactions of Parents are the same as in Table 16.)

Cross.	F_3 Reactions to Race 222AB.					
		Resistant.			Susceptible.	Total.
	(R+ to R)	(R− to SR)	(R+ to SR)	(R− to Int.)		
Marquillo × Kenya 744 ..	17	43	102	1	—	163
Marquillo × Kenya 117A ..	20	— 67	—	—	—	87
Thatcher × Kenya 744 ..	18	80	151	—	—	249

reactions were complicated by the operation of the resistance factors but there was definite evidence that 6 of these families did not yield any segregate with resistance like that of Kenya 117A. It appears that the immunity factor is not in any way related to the Kenya factor for resistance.

DISCUSSION.

The results obtained by Hayes *et al.* (1925), Neatby and Goulden (1930), Ausemus (1934), Pan (1940), Platt *et al.* (1941), Swenson *et al.* (1947), and Koo and Ausemus (1951) show that the field resistance of Marquillo or Thatcher is dependent on at least

two, three or more factors. Neatby and Goulden (1930) reported that when Marquillo was crossed with (Marquis × Kanred B_{2-5}) the operation of three or more factors was indicated, but when Garnet or Reward were used as susceptible parents, many factors appeared to be involved, and Neatby (1931, 1933) later found that Marquillo and Thatcher do not possess any additional factor for mature plant resistance, except the ones which are operative in the seedling stage. The results obtained from the present studies in the glasshouse indicate that Marquillo, Thatcher and Hochzucht present a very similar mode of inheritance against race 222AB, and most of the resistance factors in these varieties are allelomorphic and probably identical. The segregation in crosses between a susceptible and each of the resistant varieties is influenced by temperature, and results can be best explained on a multiple factor hypothesis. It was of some significance to isolate a line from the cross Federation × Marquillo which was resistant at low temperatures, and susceptible at high temperatures.

Lines homozygous for partial resistance were obtained in all crosses between Federation and Marquillo, Thatcher or Hochzucht but not one line incorporated the full resistance of the parents. This fact probably throws some light on the difficulty encountered in transferring the full resistance of Iumillo to Marquillo. It has also been seen that Thatcher and Hochzucht do not possess all the minor genes for resistance in Marquillo as a greater percentage of resistant lines was recovered in crosses involving the latter variety. The results are in agreement with those of Neatby and Goulden (1930), who suggested that Marquillo possesses one or two minor factors for field resistance in addition to those concerned in the Double Cross resistance. Powers (1932) and Love (1941) found that Marquillo shows abnormal chromosome behaviour and it is possible that Iumillo chromosomes bearing some of the resistance factors do not show complete homology with the *vulgare* chromosomes, and tend to be eliminated during meiosis. It seems, however, quite easy to transfer partial resistance from Marquillo, Thatcher or Hochzucht, as there appears to be present at least one factor in these varieties which can singly produce a resistant reaction. The presence of such a factor is of some importance in relation to the factor controlling Kenya resistance as the two appear to be strongly linked. Probably it will not be possible to combine all the major genes for resistance in Marquillo with the single factor in Kenya varieties, but it may not be difficult to couple partial resistance from the former source with the full resistance of Kenya 744 or Kenya 117A.

The results on the inheritance of Marquillo resistance at low and moderate temperatures to race 222AB show some similarity with those obtained by Harrington (1931). In the cross Marquis × Marquillo, he found a reversal in the genetic ratios when F_2 seedling families were tested to race 21 at an average temperature of about 70° F. and 61° F. Only 1/64 of the F_3 families were resistant like Marquillo at the higher temperature, while only 1/64 were found to be susceptible like Marquis at the lower temperature. Harrington explained these results by assuming that the action of three dominant genes for susceptibility present in Marquis was greatly curtailed or reduced at the lower temperature. The results obtained here show that 3 of the 149 F_4 lines of the cross Federation × Marquillo approached the resistant reaction of Marquillo at moderate temperatures, while at low temperature some highly resistant lines were obtained, and only 5 lines were homozygous for susceptibility. It was suggested that this difference in the segregation is due to the presence in Marquillo of some genes which are influenced by temperature. The resistance of Marquillo to race 21 has been found to depend mainly on the same genes which confer resistance against race 222AB.

It has been seen that Hochzucht and Thatcher appear to have the same genetic constitution both with respect to resistance and immunity to certain races of *Puccinia graminis tritici*. As the factor for immunity is not effective against Australian rusts, Thatcher and Hochzucht do not add to the genetic diversity for resistance possessed by Marquillo. Because Marquillo possesses some minor genes for resistance which are not present in Thatcher or Hochzucht, it appears more appropriate to use the former for incorporating resistance to rust in this country. It has already been found that Marquillo is slightly more resistant to Australian rusts than Thatcher and Hochzucht

at higher temperatures, and it is comparatively easy to secure a resistant line in crosses of a susceptible variety with Marquillo. The reactions in Table 1 also show that Marquillo possesses higher resistance than Thatcher and Hochzucht against certain other races of stem rust.

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THE NYMPH OF *EUSCHÖNGASTIA SMITHI* (WOMERSLEY, 1939) (ACARINA, TROMBICULIDAE).

By Robert Domrow, Queensland Institute of Medical Research, Brisbane.

(Ten Text-figures.)

[Read 29th June, 1955.]

Synopsis.

The nymph of *Euschöngastia smithi* (Wom.) is described, being the second of this genus to be correlated with its larva in Australia. The nymph emerged fifteen to nineteen days after detachment. A key to the three known nymphs of Australian *Euschöngastia* is given.

The second Australian-bred nymph of the genus *Euschöngastia* Ewing, *E. smithi* (Wom.), is described in this note. The other, *E. perameles* (Wom.), was described by the author in an earlier paper (Domrow, 1955).

On 18.i.55 a specimen of *Rattus assimilis* Gould from Mt. Glorious, south-east Queensland, was examined. Fairly numerous chiggers were found in the ears, both in small groups and singly. These were removed with a needle. Half were mounted and identified as *E. smithi*, except for one specimen of *E. derricki* (Wom.). Twelve larvae were set up in tubes after the method described by Audy and Nadchatram (1954), and fifteen to nineteen days later eight nymphs emerged. The active period lasted up to five days. After the eight nymphs had emerged some remaining larvae, which apparently were not fully engorged, were still active, but died later. The larvae were trapped by the smallest droplets of moisture, while the nymphs could move over the moist glass surface with ease.

Euschöngastia smithi (Womersley, 1939).

Types: Six morphotype nymphs in collection of Queensland Institute of Medical Research, Brisbane, and one each at South Australian Museum, Adelaide, and Institute for Medical Research, Kuala Lumpur. All nymphs are accompanied by correlated larval pelts and were bred from engorged larvae taken from inside the ears of *Rattus assimilis* Gould, Mt. Glorious, south-east Queensland, 18.i.55.

Description of Nymph.

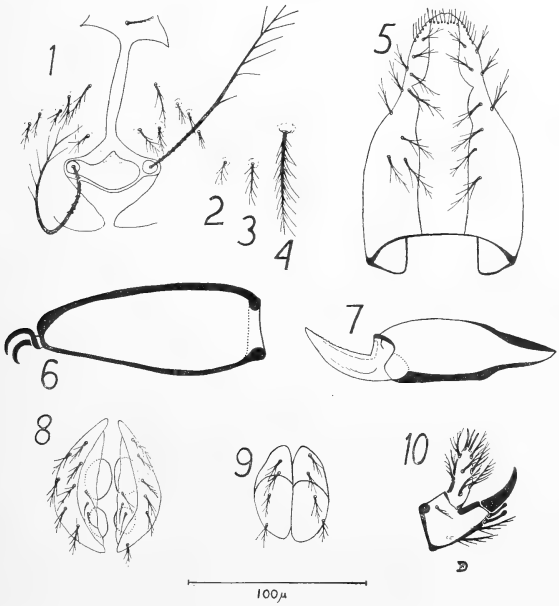
Body: Mean idiosomal length 568μ (range 470μ to 607μ), breadth across propodosoma 269μ (233μ to 296μ), across hysterosoma 288μ (249μ to 311μ); well marked constriction at level of posterior pair of coxae; pale straw colour in life. Genital area oval (Text-fig. 8), 76·8μ long, with two pairs of genital suckers; anterior sucker 18·8μ, posterior sucker 14·9μ long. Genital plates with six or seven pairs of ciliated setae; inner genitalia constantly with three pairs of setae, which may be simple or bifurcate apically; two anal plates (Text-fig. 9) 49·6μ long, rather more heavily chitinized anteriorly, normally with four pairs of ciliated setae. The genitalia are placed just behind coxae IV, and the anal plates are separated by slightly less than their own length from the genitalia.

Gnathosoma: Chelicerae (Text-fig. 7) with fine teeth dorsally; blade 52μ long. Hypostome (Text-fig. 5) blunt anteriorly, with about twenty simple setae; base of gnathosoma with nine or ten pairs of ciliated setae, which are somewhat slenderer than body setae.

Palpi (Text-fig. 10) 5-segmented, similar in shape to *E. perameles*; tibial claw 28·6μ long. Femur with three or four dorsal and one external ciliated setae; genu with six or seven dorso-lateral ciliated setae; tibia with five external and one internal ciliated setae; with two internal, dorsal, sub-apical, spatulate accessory spines in addition to

strong apical spine; tarsus with eight internal and one external ciliated setae, one external sensory rod, and three apical simple setae.

Legs: Leg I largest, leg IV longer than legs II and III, which are almost equal; all 7-segmented; coxae I with precoxal plates fused medially as in *E. perameles*. All tarsi with two strong claws (Text-fig. 6). Coxae I and II and III and IV in two distinct groups, only coxae I being fused. Tarsus I 118μ long, 53μ high; tibia I 86μ long, tarsus II 71μ long, tibia II 47μ long. Tarsus I without preapical dorsal process (Text-fig. 6); *E. perameles* also has no such process.



Text-figs. 1-10.—*Euschöngastia smithi* (Wom., 1939). Nymph. 1, Scutum. 2, Anterior dorsal seta. 3, Mid-dorsal seta. 4, Posterior dorsal seta. 5, Hypostome and basal part of gnathosoma in ventral view. 6, Tarsus I in lateral view. 7, Chelicera in lateral view. 8, Genitalia. 9, Anal plates. 10, Palpal tibia and tarsus, interior aspect.

Scutum (Text-fig. 1): Sensillary area roughly diamond-shaped, with anterior part punctate between sensillary bases. Tectum with anterior margin indistinct, and with single weakly ciliated tectal seta. Median saddle present on sensillary area, connecting sensillary bases. Chitinization around sensillary bases sometimes asymmetrical. Posterior apodeme with irregular sides, with sinuous lines diverging laterally at the apex as in *E. perameles*. Sensillae filiform, of fairly uniform thickness, but slightly thicker medially, with basal barbules, and ciliations to 20μ distally. Eyes absent. Parascutal setae one on each side with five to seven adjacent setae. The scutal standard data are given in Table 1, after Audy (1953).

Setation: Dorsal body setae (Text-figs. 2 to 4) increasing in length posteriorly from 14·2μ just behind scutum to 60·3μ at posterior margin of hysterosoma. All setae are set on platelets as in *E. perameles*, but the posterior setae are also on small tubercles on the platelet. In *E. perameles* the setation is much more uniform. The ventral setae are similar, and strongly ciliated like those on the dorsum. The setation of the legs is in general similar to *E. perameles*. Precoxal plates with three or four setae each.

Coxa I with twelve to eighteen, coxa II with eight or nine, coxa III with eight to fifteen, and coxa IV with nine to fifteen ciliated setae.

Taxonomic Notes.

Like *E. perameles*, the nymph of *E. smithi* also runs readily to caption 10 in Womersley's key (1952, p. 366), and may be separated from *E. mutabilis* by its longer sensillae and the nature of the dorsal hairs, and from *E. nadchatrami* by its much smaller size, short crista, and the presence of precoxal plates. The larvae of all three species are quite distinct. *E. smithi* and *E. perameles* appear to be much more closely related to one another, both in larval and nymphal stages, than to either of the last two species. The following key is offered to separate the three known nymphs of Australian *Euschöngastia* Ewing.

TABLE 1.

Standard Data (in Micra) of Scutum of E. smithi.

	CTL	ASL	SB	$\frac{ASL}{SB}$	PSL	PAD	TS	SS	SENS
	71·4	82·1	48·2	1·70	14·3	32·1	15·0	27·5	123·2
	75·0	85·7	—	—	12·5	35·7	16·1	28·6	117·8
	71·4	85·7	42·8	2·00	14·3	32·1	14·3	26·8	117·8
	71·4	83·9	41·1	2·04	—	—	—	28·6	—
	67·8	80·3	41·1	1·95	16·0	30·3	16·1	28·6	117·8
Means..	71·4	83·5	43·3	1·92	14·3	32·6	15·4	28·0	119·2

Key to nymphs of Australian Euschöngastia.

1. Precoxal plates absent, sensillae slightly clavate ..... *E. indica* (Hirst).
   Precoxal plates present, sensillae filiform ..... 2.
2. Dorsal setae relatively uniform in length, 23-32μ long; precoxal plates with about seven setae each; anal plates with about six pairs of setae; no simple inner genital setae; a larger species, 720 to 780μ long; known only from *Isoodon obesulus* .... *E. perameles* (Wom.).
   Dorsal setae increasing in length posteriorly, 14 to 60μ long; precoxal plates with three or four setae each; anal plates with four pairs of setae; three pairs of simple inner genital setae present; a smaller species, 470-600μ long; known only from *Rattus assimilis* ..... *E. smithi* (Wom.).

Acknowledgements.

Thanks are due to Drs. E. H. Derrick and I. M. Mackerras for their interest and criticism, and to Mr. K. E. H. Webber and Dr. W. A. McDougall, who supplied and identified the host.

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A NEW SPECIES OF *ECHINONYSSUS* HIRST, 1925, FROM QUEENSLAND (ACARINA : LIPONYSSINAE).

By Robert Domrow, Queensland Institute of Medical Research, Brisbane.

(Two Text-figures.)

[Read 29th June, 1955.]

Synopsis.

Echinonyssus validipes, n. sp., from the rat-kangaroo, *Potorous tridactylus,* from Queensland is described and discussed. A key to the two known species is given.

Recently two rat-kangaroos (*Potorous tridactylus* Kerr) from south-east Queensland were examined for ectoparasites. They yielded some very interesting mites belonging to a new species of *Echinonyssus* Hirst, 1925 (Liponyssinae). The other species of the genus (*E. nasutus* Hirst, 1925) is recorded only as a single specimen from the Oriental tree-shrew, *Tupaia picta,* from Sarawak.

Echinonyssus validipes, n. sp.

Types: The holotype female, allotype male, paratype males, and morphotype nymphs are in the collection of the Queensland Institute of Medical Research, Brisbane. Paratypes of both sexes are also in the South Australian Museum, Adelaide. The type series was collected on two rat-kangaroos, *Potorous tridactylus* Kerr, Mt. Nebo, south-east Queensland, 24.ix.54 and 17.i.55.

Female (Text-fig. 1).

A small, pale, weakly chitinized species; idiosoma length 660μ, breadth 455μ. *Dorsal shield* not completely covering dorsum, slightly constricted medially; twenty pairs of very small setae on dorsal shield; thirteen pairs of somewhat longer setae on dorsal marginal cuticle. *Peritreme* very short, situated dorsally above coxa III; stigma slightly swollen.

Venter. Sternal shield large, narrower anteriorly, and slightly convex posteriorly; three pairs of fine sternal setae and two pairs of punctate pores present. Genito-ventral shield drop-shaped, with two pairs of short setae; genital operculum large, extending forward well past centre of sternal shield, and with numerous very fine longitudinal striations (not shown in illustration). Anal shield elongate, with heavier chitinizations laterally; all three anal setae weak. Ventral cuticle striated, with about twelve pairs of simple setae. Tritosternum present, with weakly ciliated lacinae.

Legs. All coxae with heavily chitinized spurs; anterior ventral margin of coxa II with large hook, which curves ventrally and caudally, being used to grasp the fur of the host. Smaller, retrorse spurs present ventrally on tibia and genu I, and on tarsi, tibiae, and genua III and IV. Femora I and II with long seta dorsally, while femur I also has a chitinized process with a small, apical seta.

Chelicerae weakly chitinized, long, and slender, 213μ; two digits about equally developed, straight, blade-like, and without teeth; blades 66μ long and up to 7·1μ wide.

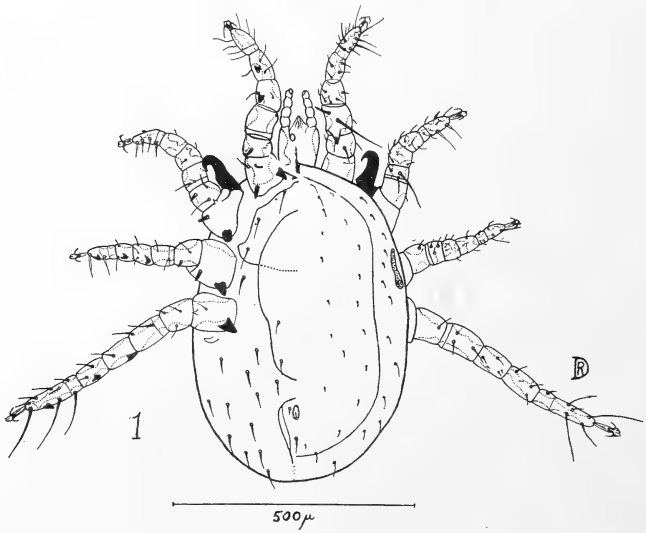
Male (Text-fig. 2).

Most specimens are approximately equal in size to female (670μ long, 443μ wide), but odd ones are somewhat larger; more heavily chitinized, and with much stronger legs. *Dorsal shield* larger, and not constricted medially; with 31 pairs of setae, of which eleven anterior marginal and three discal pairs are weak, five posterior pairs are strong, and twelve discal pairs are in the form of stout, blunt spines. Dorsal marginal cuticle with about seven pairs of simple setae. *Peritreme* as in female.

Venter. Sternal, metasternal, and genito-ventral shields fused to form holoventral shield. Sternal and metasternal setae and pores as in female; genital aperture on anterior margin of sternal area. Ventral area with four pairs of setae. Holoventral shield with longitudinal lines of weakness, along which the shield splits on application of undue pressure. Anal shield separate from holoventral shield, and similar to female. Ventral cuticle striated, with about eleven pairs of simple setae. Tritosternum as in female.

Legs. All coxae with heavily chitinized spurs; coxa II without large hooks; coxa IV also with long, simple seta. All other segments of legs I and II (except tarsus I and tibia II) with retrorse spurs ventrally, and with normal setae dorsally, except for long seta on femora I and II. Femur II with large flask-shaped club ventrally. Legs III and IV with setation very strong ventrally and less so dorsally.

Chelicerae with blade-like, untoothed digits, which are shorter than in female; blades 39μ long.



Text-fig. 1.—*Echinonyssus validipes*, n. sp. Female. Left, ventral view; right, dorsal view.

Nymph.

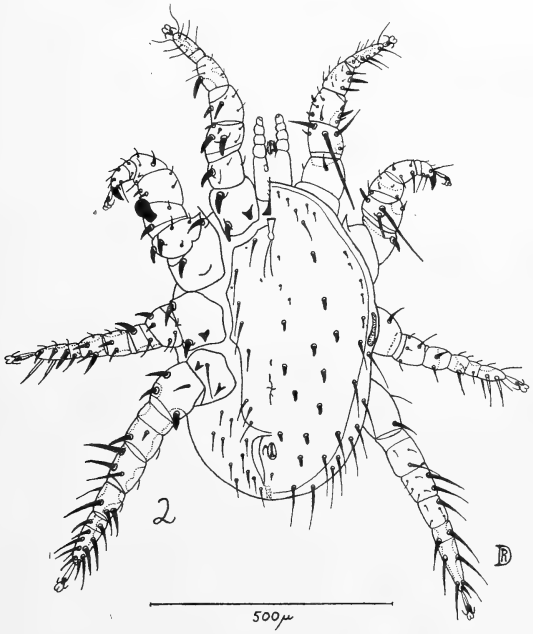
The following notes are based on two nymphs, in both of which a developing male is visible. *Dorsal shield* entire, with nineteen pairs of simple setae, made up of twelve pairs of long marginal, three pairs of very small anterior discal, and four pairs of longer posterior discal setae. *Peritreme* as in adult.

Venter with elongate-oval shield (somewhat narrower than male holoventral shield) extending from just behind base of tritosternum to level of posterior margin of coxae IV; with five pairs of setae (representing future sternal, metasternal, and genital setae). Anal shield separate and similar to adult.

Legs with armature and setation generally similar to adult, but not so well developed; apical spur on tarsus II and club on femur II absent, but adult structures clearly visible beneath nymphal cuticle.

Distribution.—Known only from the type locality and host in south-east Queensland.

Taxonomic notes.—Hirst (1925) erected the genus *Echinonyssus* for a single specimen of *E. nasutus* Hirst, 1925. He stressed as a generic character, being followed by da Fonseca (1948), the forward projection of the dorsal shield into a large, median, hook-like process. Dr. G. Owen Evans, of the British Museum, has kindly re-examined the specimen for me, and believes "the anterior hook is a prolongation of the heavily sclerotized vertex". *E. validipes* does not possess this process, but the female has the following important characters in common with Hirst's species: an immense hook on coxa II, all coxae heavily armed, and setae of dorsal shield very short and inconspicuous. The following key (also partly based on Dr. Evans' information) will serve to separate the females of the two species.



Text-fig. 2.—*Echinonyssus validipes*, n. sp. Male. Left, ventral view; right, dorsal view.

Key to females of the two known species of Echinonyssus *Hirst.*

1*a*. Dorsal anterior hook present on vertex; sternal shield reduced, concave posteriorly; genito-ventral shield with one pair of setae (the second pair figured by Hirst being actually in slight emarginations of the shield); peritreme extending forward beyond coxa II; no long setae present dorsally on femora I and II; apical segments of legs without retrorse spurs ..... *E. nasutus* Hirst, 1925.

1*b*. Dorsal anterior hook absent; sternal shield not reduced, slightly convex posteriorly; genito-ventral shield with two pairs of setae; peritreme much reduced, situated over coxa III; long seta present dorsally on femora I and II; some apical segments of legs with retrorse spurs ..... *E. validipes*, n. sp.

The relationship of the hosts must also be kept in mind. *Tupaia* is a typically Oriental insectivore (Eutheria), while *Potorous* is a typically Australian marsupial (Metatheria). However, in the absence of the male of *E. nasutus*, a new genus has not been erected for *E. validipes*, even though it differs markedly in some characters from Hirst's species.

Acknowledgements.

My sincere thanks are due to Dr. G. Owen Evans, who so kindly re-examined Hirst's original specimen for me. I am also indebted to Dr. G. C. Taylor and Mr. T. Lawton, who supplied the hosts, to Dr. E. H. Derrick for his interest, to Dr. I. M. Mackerras for reading my manuscript, and to Mr. H. Womersley for his kind advice.

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NOTES ON THE AUSTRALIAN RUTELINAE (SCARABAEIDAE, COLEOPTERA).

SUPPRESSION OF A GENERIC NAME UNDER CLILOPOCHA LEA.

By P. B. Carne.*

[Read 25th May, 1955.]

Synopsis.

Dynastomorphus Carne (1954) is shown to be a synonym of the monotypic genus *Clilopocha* Lea (1914): the latter was erroneously placed by its author in the subfamily Melolonthinae. With a slight modification the generic characterization of *Dynastomorphus* is applicable to *Clilopocha* Lea, which now consists of the following species: *C. whiteae* Lea (type species), *C. pilosicollis* (Lea), n. comb., *C. pachypus* (Lea), n. comb., *C. angularis* (Carne), n. comb., *C. mandibularis* (Carne), n. comb.

The generic name *Dynastomorphus* Carne was proposed for four species of dynastine-like Ruteline beetles, two of which were described by Lea in the Dynastine genus *Aneurystypus*.

Mr. E. B. Britton of the British Museum has sent the writer a specimen of *Clilopocha whiteae* Lea with the comment that he could not accept it as a Melolonthine. Lea erected this monotypic genus and considered it most closely related to *Dysphanochila* Blackb. in the Melolonthinae. The species is, however, a typical *Dynastomorphus*, closely related to *angularis* Carne.

The name *Dynastomorphus* must therefore be placed in synonymy under *Clilopocha* Lea.

Clilopocha Lea.

Clilopocha Lea, *Trans. Roy. Soc. S. Aust.*, XXXVIII, 1914: 452.—*Dynastomorphus* Carne, *Proc. Roy. Ent. Soc.* (B), 23, 1954: 36 (SYN. N.).

Type species: *Clilopocha whiteae* Lea, 1914.

The addition of a fifth species to this assemblage requires no modification of the generic characterization published for *Dynastomorphus* beyond the deletion of the phrase "anterolateral angles obtuse" in reference to characters of the pronotum.

From *mandibularis* Carne, *whiteae* differs in its cephalic profile (which is almost identical with that of *angularis* Carne) and in its lack of decumbent pygidial setae. From *angularis* it differs in having the clypeus strongly punctate, the elytra without conspicuous striae but with dorsal vestiture. From both species it differs in having the mandibles only slightly produced beyond the clypeus and in having elytra with conspicuously membranous lateral margins. From Lea's species, *pachypus* and *pilosicollis*, it differs in its coarsely tridentate fore tibiae bearing evident spurs, in its highly transverse clypeus and its anteriorly arcuate clypeofronta[1] suture.

C. whiteae is known only from three type specimens in the South Australian Museum; all were taken in the MacDonnell Ranges by Capt. S. A. White.

The following new combinations are to be noted: *Clilopocha pachypus* (Lea); *Clilopocha pilosicollis* (Lea); *Clilopocha angularis* (Carne); *Clilopocha mandibularis* (Carne).

* An officer of the Division of Entomology, C.S.I.R.O., Canberra.

AUSTRALIAN RUST STUDIES. XIV.

Investigations of Rust of Maize caused by Puccinia sorghi Schw.

By W. L. Waterhouse, The University of Sydney.

(Plate v.)

[Read 25th May, 1955.]

Synopsis.

Five aecidial and seven uredospore cultures of *Puccinia sorghi* Schw. from New South Wales and Queensland were used in a comparative study of the reactions shown by strains of inbred maize from N.S.W., Queensland, and U.S.A. No evidence of specialization was shown, all inbreds showing seedling susceptibility; there was evidence that mature plant resistance sometimes occurs. An inbred maize from Minnesota, U.S.A., named "Golden Glow 208" was resistant to all cultures. It was crossed with an inbred strain of "Funk's Yellow Dent", and gave F_1 and F_2 evidence of its resistance being due to a single dominant gene which is inherited independently of the dominant gene in "Funk's Yellow Dent" for coloured coleoptile.

Introduction.

Rust on maize caused by *Puccinia sorghi* Schw. has been known in Australia since 1890 (Noble *et al.*, 1934), and in favourable seasons does serious damage to the foliage and thus reduces the yield. This has become increasingly noticeable with the greater popularity of sweet corn in horticultural practice, where environmental conditions are generally more favourable for rust development than under field conditions.

The Pathogen.

Until 1946 only the uredo- and teleutospore stages of the fungus had been recorded. In that year, viable teleutospores sent from Glen Innes on maize trash that had been exposed to the severe winter conditions of the Tablelands were used to inoculate plants of *Oxalis corniculata* L. growing in pots in the plant house. Abundant production of spermogonia and aecidia followed, and from the latter, cultures on seedling maize plants were developed and maintained in the plant house. It was found that this uredospore material, if air-dried in the laboratory, and kept in a refrigerator at $\pm$ 3° C., remained viable for several months.

Following upon this production of the aecidial stage, a search was made for it under natural conditions in the field. It was found at Manly in the Sydney metropolitan area, Bega, Grafton, and Glen Innes: in all cases the alternate host was growing as a weed in areas in which maize had been cultivated. In all cases uredo-cultures were developed and maintained in the plant house on maize seedlings.

Specialization.

The occurrence of physiologic races of the rust has been recorded in U.S.A. Stakman *et al.* (1928) found 7 races, and Mains (1931) determined 3 races by the use of a different set of differentials. Their host material has not been available for use here.

For the local studies the following cultures were used: *Aecidial cultures* from Manly (2), Bega, Grafton, Glen Innes. *Uredo-cultures* from Manly, Bega, Grafton, Glen Innes, Hermitage Q., Toowoomba Q., and Ayr Q.

Cultures were maintained on seedlings of the maize variety "Funk's Yellow Dent", kindly supplied by the N.S.W. Department of Agriculture. The inoculum was built up into quantities sufficient for inoculation work as required. From time to time albino seedlings showed up in the pots (Plate v, A). Seedlings growing in 4-inch pots in the

plant house were used throughout the work: the leaves were moistened, the uredospores transferred to them with a sterile scalpel, and the pots then incubated for a period of 36–48 hours, depending upon the weather, and afterwards kept on well-lighted benches in the plant house until the reactions were fully developed. No differences in reactions owing to high or low temperatures were noted.

In note-taking the separation into resistant and susceptible plants gave no trouble (Plate v, B), but the following notation was used:

0; = Resistance: tiny scattered flecks on leaves.
1 = Resistance: very small pustules on necrotic spots.
X–= Resistance: a mixture of flecks with very small and rather large pustules on necrotic areas.
4 = Susceptibility: abundant production of uredo-pustules without necrosis, often coalescing to form large lesions.

Host material for the tests was kindly supplied in 1947 by Mr. W. W. Bryan of the Queensland Department of Agriculture, and by Mr. W. T. Atkinson of the N.S.W. Department of Agriculture; later, at the request of Dr. E. P. Baker, Dr. H. K. Hayes of the University of Minnesota forwarded a selection of his material.

The Queensland inbreds were as follows, in which the first numeral is the Gatton Accession Number:

144 U.S.D.A. Line X, 263 Wisconsin 7945, 269 Wisconsin A1237, 270 Wisconsin R4, 272 Wisconsin I90, 275 Wisconsin 132, 294 Missouri K1, 295 Missouri H3, 296 Missouri N12, 317 Minnesota 11, 326 Nebraska 365–2046A, 327 Nebraska Wahl 2010A, 328 Nebraska 111-2066A, 332 Iowa L317B2, 346 Indiana 54, 347 Indiana 66, 348 Indiana T.R., 376 Wisconsin CR11, 378 Wisconsin B10, 447 Kansas Y.S.50, 579 Wisconsin 32, 637 Iowa B111S, 752 Colorado A–1 Argentina, 811 E.W. Iowa 8273–2.

The N.S.W. inbreds were:

701, Tr, A, I205, 4–8, 187–2, HY2, L317, 38–11, W19, K4, R4, 5120, 2 (selfed), 21 (selfed), 25 (selfed), 25 × 21, D07 (selfed), D07 × 21, 61 (selfed), R.H96A.

The seedling tests with the Australian inbreds in every case revealed a susceptible reaction similar to that shown by the "Funk's Yellow Dent" control. No differences were found between the cultures.

This is at variance with the reported field behaviour of certain of the lines. For example, the N.S.W. inbreds 701 and 5120 were stated by Mr. W. T. Atkinson to have a high tolerance or useful resistance to the rust at Glen Innes (personal communication, 1948). Seeing that both aecidial and uredo-cultures from Glen Innes were used (the latter isolated in 1947), it seems likely that there is no correlation in these cases between seedling and mature plant behaviour to rust attack. Such development of mature plant resistance is well established in certain of the cereal rusts.

The U.S.A. material comprised a number of inbred lines, including one of pod corn (*Zea mays tunicata*). All proved susceptible, with the exception of "Golden Glow 208", which was resistant throughout. Three strains of teosinte (*Euchlaena mexicana* Schrad.) proved strongly resistant to all the cultures with the exception of the Glen Innes aecidial culture, which produced a susceptible reaction on one of the strains. This was the only indication of a differential reaction in all the tests.

Crossing Work.

The resistant "Golden Glow 208" was crossed in the plant house in 1949 and 1950 with an inbred selection of "Funk's Yellow Dent". This had its origin in a chimeric cob collected in the Moruya District by Dr. N. H. Parbery (Plate v, C). Its progeny were susceptible in all subsequent seedling tests. Grain from the deep red sector on the cob gave plants which bred true for this deep colour, whilst 2 from the border which were partly red and partly yellow produced normal "Funk's Yellow Dent" grain.

The F1 seedlings gave a resistant reaction recorded as "X–". Their cobs, produced in pots in the plant house, were stunted but gave sufficient grain for F2 tests.

The F2 results from 5 cobs tested with the Hermitage culture are set out in Table 1, together with the expected results on a 3:1 basis.

TABLE 1.

Numbers of Plants in Different Classes from Tests of F_2 Seedlings of "Funk's Yellow Dent" × "Golden Glow 208".

Cob.	Observed.		Expected.	
	Resistant.	Susceptible.	Resistant.	Susceptible.
A	42	14	42	14
B	49	14	47·25	15·75
C	31	12	32·25	10·75
D	26	11	27·75	9·25
E	107	42	111·75	37·25
Totals ..	255	93	261	87

$P = > 0{\cdot}30$.

It is clear that a single dominant factor determines resistance in the seedling stage. This is in accord with the U.S.A. determinations (Mains, 1931).

The seedlings of "Funk's Yellow Dent" show pigmentation of the coleoptile, whilst those of "Golden Glow 208" are white. The F1 seedlings were coloured, and in the F2, segregation into the two colour classes was observed.

The progeny of one cob were classified on the basis of coleoptile colour and rust reactions, and gave results as shown in Table 2.

TABLE 2.

Numbers of Individuals Falling into the Different Classes, together with the Expectancy on a 9 : 3 : 3 : 1 Basis.

Class.	Observed.	Expected.
Resistant, coloured	59	65·81
Resistant, white	25	21·94
Susceptible, coloured	23	21·94
Susceptible, white	10	7·31
Totals	117	117

$P = > 0{\cdot}50$.

It is clear that the two characters are inherited independently. Mains (1931) did not detect linkage with any of the characters studied.

CONCLUSION.

The demonstration of the absence of specialization and the simple inheritance of rust resistance would indicate that little difficulty should be experienced in breeding resistant commercial types of maize. "Golden Glow 208" itself may be found to be a suitable inbred for crossing with particular inbreds to produce "hybrid corn". No attempt was made to determine its combining ability.

Acknowledgements.

Mr. W. W. Bryan of the Queensland Department of Agriculture, Mr. W. T. Atkinson of the N.S.W. Department of Agriculture, and Dr. H. K. Hayes of the University of Minnesota supplied host material, and officers of the N.S.W. Department of Agriculture some of the diseased specimens and maize grain. My daughter (E.R.W.) gave assistance with the manuscript, and financial assistance came from the Commonwealth Bank and the Rural Bank of N.S.W. To all grateful thanks are tendered.

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EXPLANATION OF PLATE V.

A. Pot of "Funk's Yellow Dent" seedlings showing the occurrence of an albino. × $\frac{3}{5}$.

B. Seedling leaves showing from left to right the following reactions: "O;", "4" (Parents), and "X–" (F_1). Nat. size.

C. Cob of "Funk's Yellow Dent" maize showing sectorial chimera. × $\frac{1}{2}$.

A NEW SPECIES OF *CIDAPHUS* FOERSTER FROM AUSTRALIA, WITH A NOTE ON THE SYSTEMATIC POSITION OF *TETRAGONALYS PAGANA* MORLEY.

By Arthur W. Parrott.

(Two Text-figures.)

[Read 29th June, 1955.]

Synopsis.

A new species of *Cidaphus* Foerster is described and figured from Australia. This new form appears to be closely allied to *Tetragonalys barbarica* Morley, a Himalayan species, described and designated the type species of a new genus by Morley in 1913. Cushman (1924) synonymizes *Tetragonalys* Morley with *Cidaphus* Foerster. About the time he erected the genus *Tetragonalys* for the Himalayan species, Morley described another species, *T. pagana,* from Victoria, Australia, which proves to be an entirely different insect from *T. barbarica,* the type species of the genus. Three specimens in the National Museum of Victoria, Melbourne, bred from the same host as Morley's types of *T. pagana,* and which agree in every detail with Morley's description of the latter species, prove to be congeneric with a species described by Szepligeti in 1908 from Western Australia, under the name *Megaceria opheltes.* A re-description of *Megaceria pagana* (Morley) and a key to separate the two known Australian species are given.

The material on which the following observations are based is in the collections of the National Museum of Victoria, Melbourne.

Subfamily Mesochorinae.

Genus Cidaphus Foerster.

Cidaphus Foerster, 1868, *Naturh. Ver. Rheinlande Verh.*, 25: 149.

Plesiophthalmus Foerster, 1868, *Naturh. Ver. Rheinlande Verh.*, 25: 170.

Mater Schulz, 1911, *Zool. Ann.*, 4: 22. (New name for *Plesiophthalmus.*)

Tetragonalys Morley, 1913, *Rev. Ichn. Brit. Mus.*, Pt. 2:132.

Plesiophthalmidea Viereck, 1914, *U.S. Nat. Mus., Bull.* 83: 119.

Ophthalmochorus Roman, 1925, *Arkiv for Zool.*, 17a, (4): 29. (New name for *Plesiophthalmus.*)

Type species, *Mesochorus alarius* Gravenhorst.

Cushman (1924: 4) synonymizes *Plesiophthalmus* Foerster, *Tetragonalys* Morley and *Plesiophthalmidea* Viereck with *Cidaphus* Foerster. In accepting *Cidaphus* to replace *Plesiophthalmus* I follow Cushman and the majority of European authors. *Mesochorus alarius* Gravenhorst is the accepted type species of the two genera, but *Cidaphus* has page precedence, in addition to *Plesiophthalmus* being preoccupied by Motschulsky in 1857. This being the case, it is necessary to use *Cidaphus* as the generic name. *Plesiophthalmidea* Viereck was proposed for *Plesiophthalmus paniscoides* Ashmead but, as Cushman points out, this species is certainly congeneric with *alarius* Gravenhorst, and there is no reason for the erection of another genus. Townes (1951: 405) synonymizes *Mater* Schulz and *Ophthalmochorus* Roman with *Cidaphus* Foerster, as both of these names were proposed to replace the preoccupied name *Plesiophthalmus* Foerster.

When Morley erected the genus *Tetragonalys* for a Himalayan species he also included a species from Australia. The Australian species is certainly not congeneric with *T. barbarica* Morley from Sikkim, Tibet, but, as will be pointed out later in this paper, belongs to *Megaceria* Szepligeti, a very distinct genus originally described from Western Australia.

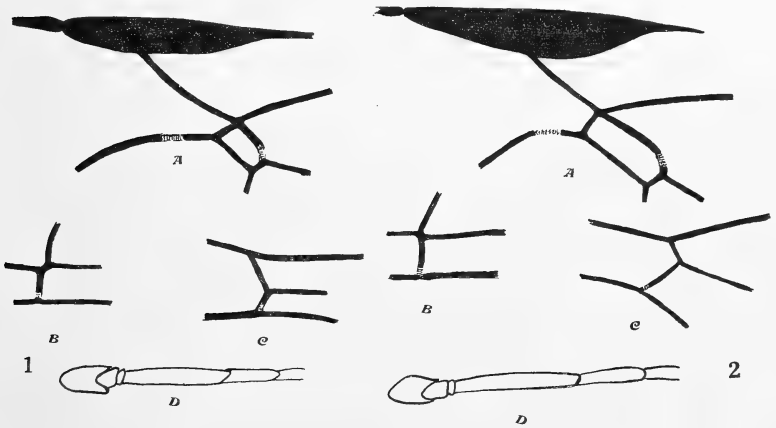
Recently I was delighted to find a specimen of *Cidaphus* in the collections of the National Museum of Victoria, Melbourne. This specimen is a typical *Cidaphus*, as defined by Cushman (1924), and apparently closely related to Morley's *Tetragonalys barbarica* Morley from Tibet.

CIDAPHUS GLABROSUS, n. sp. (Text-fig. 1.)

Female 13 mm. in length.

A testaceous species with the mandibular teeth, stemmaticum and a spot behind the base of the forewings black; the head entirely brown, including the face, the stigma yellow-testaceous with the veins of the forewings darker, but those of the hindwings light testaceous; claws are dark brown.

Internal orbits emarginate slightly above the base of the antennae; face and clypeus distinctly but not closely punctate; clypeus flat, weakly separated from the face, with the anterior margin very broadly rounded; mandibles stout with the teeth subequal in length; ocelli large, lateral ocelli not contiguous with the eyes; malar space absent; antennae about as long as the body, scape ovate, and are moderately incised apically; flagella with 53 segments, with the first twice as long as second (Text-fig. 1, D), the second and third subequal in length; mesonotum shining, minutely punctate; notaulices obsolete, except anteriorly; posterior lateral borders of the mesonotum are strongly reflexed



Text-fig. 1.—*Cidaphus glabrosus*, n. sp. A, Portion of forewing showing areolet and adjacent veins; B, Nervulus; C, Nervellus; D, Scape and two basal segments of flagellum.

Text-fig. 2.—*Megaceria pagana* (Morley).—A, portion of forewing, showing areolet and adjacent veins; B, Nervulus; C, Nervellus; D, Scape and two basal segments of flagellum.

above base of forewings; basal fovea of scutellum shallow, wide, smooth and shining; scutellum without lateral carinae, weakly convex and sparsely punctate, shining; basal fovea of propodeum wide, smooth and shining; areolation of propodeum incomplete, a transverse incomplete carina situated about one-third from base, and a longitudinal carina extends each side to a point about two-thirds from the base; the above-mentioned carinae outline the external and dentiparal areae; propodeum is largely impunctate and shining but the external areae are somewhat transversely wrinkled; cristulae well developed but not connected by a transverse carina; spiracles circular; mesopleurae shining and depressed centrally; sternaulices are wide and deep and clearly marked; prepectal carina is deeply emarginate above and below the middle of its length, giving it the appearance of a strongly undulating line; mesopleurae smooth on lower half but strongly crenulated on the upper half; anterior tibiae with only one spur; the intermediate and posterior tibiae have two spurs, the inner being slightly the longer; the inner posterior tibial spur is a little over one-quarter the length of the metatarsal segment; petiolar segment of the abdomen with the spiracles situated a little beyond the middle of the segment, being 0·66 the length of the segment from the base; second tergite twice the length of the postpetiole, lateral grooves or glymmae of the petiolar

occupy the apical three-quarters of the distance from the base to spiracles; abdomen shining, almost smooth with short and fine pubescence, more particularly on the posterior segments; ovipositor 0·46 the length of the petiolar segment, very fine and needle-like; all tarsal claws with somewhat coarse pectinations; there are about eight such pectinations on the posterior claws; areolet in forewing (Text-fig. 1, A) subrectangular, petiolate and oblique, almost twice as long as broad; discocubitus curved gently about the middle; subdiscoideus arising from about the middle of the branchial cell; nervulus (Text-fig. 1, B) antifurcal by about 0·17 of its length; abscissula ia 2·8 as long as the intercubitella; nervellus inclivous, upper abscissa weakly arcuate and three times the length of the lower abscissa; wings hyaline and iridescent.

Holotype: Female, Victoria, Australia (National Museum of Victoria).

This species appears to be closely related to *Cidaphus barbarica* (Morley) described from a single male specimen captured at Gyangtse in Sikkim during the Tibet Expedition in June, 1904, at an altitude of 13,000 feet. As far as can be ascertained from Morley's description of *C. barbarica* the present species differs in that the propodeum is not completely areolated and both the inner and outer claws are clearly pectinate, and that the pronotum is not stramineous and concolorous with the stigma. *C. glabrosus* differs from North American species in the form of the glymmae on the petiolar segment of the abdomen and in the areolation of the propodeum as well as in many other details of structure. Cushman (1924: 2) places *Cidaphus* in the Mesochorini, now recognized as a subfamily, and from the characters exhibited in the present specimen I concur with that opinion.

Subfamily Megacerinae.

This subfamily was erected by Szepligeti for the reception of a unique female, *Megaceria opheltes*, collected by the Michaelsen and Hartinger Expedition to south-west Australia in 1905. It is closely related to the Phytiodentini, but differs in the non-pectinate claws, the position of the spiracles of the petiolar segment, which are situated about the middle of the segment, and by the absence of lateral foveae or glymmae between the base and spiracles. Superficially it has the colouring and facies of *Netelia*, and in the form of the areolet it resembles *Cidaphus glabrosus* Parrott described above.

Genus Megaceria Szepligeti.

Megaceria Szepligeti, 1908, Die Fauna Sudwest-Australiens, p. 322, pl. 3, fig. 2. (Type species, *M. opheltes* Szepligeti.)

In the collections of the National Museum of Victoria, Melbourne, there are three specimens (one male and two females) which must be referred to this genus. These specimens undoubtedly belong to a species described by Morley from Victoria in 1913, and included by that author in the genus *Tetragonalys* Morley, which he had previously established for a Himalayan species, *T. barbarica*, which in 1924 Cushman synonymized with *Cidaphus* Foerster. The Australian species, included by Morley in *Tetragonalys*, would appear from his own description a very different insect, and certainly is not congeneric with the type of the genus. Morley's description of *T. pagana* from Victoria and Szepligeti's description of *Megaceria opheltes* from south-western Australia leave no doubt in my mind that these two species are not only congeneric but are closely allied, and that *T. pagana* Morley must be transferred to *Megaceria* Szepligeti. The three specimens in the National Museum of Victoria collections, mentioned above, undoubtedly belong to Morley's species described in 1913 as *Tetragonalys pagana* from Victoria, which in future must be known as *Megaceria pagana* (Morley).

Megaceria pagana (Morley) was originally described from a male and a female bred by C. French from a pupa of the lepidopteron *Mnesampela privata* Gn. during August, 1900, at Melbourne. The three specimens in the National Museum were bred from the same host during May and June, 1893.

The following description will serve to supplement Morley's somewhat brief diagnosis of this species.

MEGACERIA PAGANA (Morley).

Tetragonalys pagana Morley, 1913, *Rev. Ich. B.M.*, Pt. 2, p. 132.

Male 14 mm. in length.

Head, thorax, propodeum and abdomen dark brown; legs and antennae lighter brown; teeth of mandibles black-brown; stemmaticum dark brown; apical five segments of flagellum and sides of abdomen infuscated; veins of forewings dark brown except basal third of costa, which is light testaceous; stigma light yellow-brown; veins of hindwings light brown.

Face 1·55 as broad as long, finely and evenly punctate; clypeus 1·75 as long as broad, anterior margin truncated, shining, with a few large, deep setiferous punctures; eyes large, strongly convex reaching to the base of the mandibles, internal orbits emarginate, a little above the base of the antennae; scape ovoid, moderately incised apically (Text-fig. 2, D); flagellum of 63 segments, first two and a half times as long as the second (Text-fig. 2, D); the latter subequal in length to the third segment; second segment 2·6 as long as wide, the intermediate segments about 1·4 as long as wide; mandibles wide and massive, teeth subequal in length; thorax very minutely and closely punctate, mesonotum with the notaulices present but not deeply impressed; scutellum finely punctate, without lateral carinae; metapleurae strongly convex or inflated, especially when viewed dorsally, and bordered by strong carinae, and minutely punctate, the punctures much finer than those on the mesopleurae; propodeum shining, finely and obsoletely punctate, with a strong transverse carina, situated a little beyond the middle of the segment and joining the cristulae on either side; two very short median, longitudinal carinae on anterior portion, forming a minute median tubercle; with the exception of a weak longitudinal carina on each side separating the spiracular areae there are no definite areae defined on this anterior portion of the propodeum; spiracles oval and somewhat raised by a surrounding carina; posterior portion of the propodeum has a strong carina defining clearly the posterior lateral areae, the remainder smooth and shining; abdomen with the petiolar segment weakly dilated anteriorly with a slight constriction at the spiracles, which are situated at about 0·4 of the length of the segment from the base, being slightly nearer the base than to the apex; second tergite subequal in length to the post-petiole, this and the succeeding tergites moderately compressed; posterior tibial spurs short, about a quarter the length of the metatarsal segment; claws small, curved at apex and without pectinations. Venation: origin of radius slightly nearer the base than to apex of stigma and slightly arcuate; areolet (Text-fig. 2, A) large, subrectangular and almost sessile; second transverse cubital strongly bent in apical half; areolet twice as long as high; second recurrent vein except for a slight bend at the broad fenestra which is situated in the upper half; nervulus (Text-fig. 2, B) weakly postfurcal by about 0·2 of its length; abscissula 2·3 the length of the intercubitella; nervellus (Text-fig. 2, C) reclivous, broken at about its upper third, the lower abscissa 2·3 as long as the upper abscissa.

Female similar in colour and structure to the male, except that the first segment of the flagellum is about 2¼ times the length of the second segment, and the intermediate segments are about 2·3 as long as broad; the number of segments in the flagellum (57) is less than is the case in the male. The ovipositor is short, subexserted, hardly reaching the apex of the abdomen.

Specimens examined: One male and two females reared from *Mnesampela privata* (Lepidoptera), Victoria, Australia, during May and June, 1893 (National Museum of Victoria, Melbourne).

Megaceria pagana (Morley) is very similar to Szepligeti's Western Australian species *M. opheltes*, but the two species may be separated as follows:

Face finely rugose, clypeus weakly punctate; abscissula of hindwings about four times the length of the intercubitella; a yellow-brown species ..... *M. opheltes* Szep.

Face closely and finely punctate, clypeus shining with several deep and large setiferous punctures; abscissula 2¼ times to 2½ times the length of the intercubitella; a dark-brown species ..... *M. pagana* (Mor.).

Acknowledgements.

I wish to express my thanks to Mr. R. T. M. Pescott, Director, and to Mr. Alex Burns, Curator of Insects, National Museum of Victoria, Melbourne, for the loan of this interesting material. This work on Australian Ichneumonidae is being financed by grants from the Science and Industry Endowment Fund, Melbourne, the National Museum of Victoria, Melbourne, the New South Wales Department of Agriculture, and the Waite Agricultural Research Institute, Adelaide. To the Directors of these institutions and to Dr. A. J. Nicholson, Chief, Division of Entomology, C.S.I.R.O., Canberra, I wish to express my thanks for their co-operation and interest in my work.

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A NEW SPECIES OF *PROCTOTRUPES* REARED FROM THE FERN WEEVIL (HYMENOPTERA, PROCTOTRUPIDAE).

By E. F. Riek.

[Read 25th May, 1955.]

Synopsis.

There is only one previous host record for an Australian representative of the family Proctotrupidae. A new species of *Proctotrupes*, which was reared from the fern weevil (*Syagrius fulvitarsus* Pascoe), is described in this paper.

Practically nothing is known of the biology of the Australian representatives of the family Proctotrupidae, so it is of interest to record at least the host of one of the species. The only other host record is for *Proctotrupes janthinae* (Dodd) which was bred from the larva of the fungus beetle, *Thallis janthina* (family Erotylidae).

Pemberton (1921) in a search for parasites of the fern weevil (*Syagrius fulvitarsis* Pascoe) in coastal New South Wales reared only the ichneumonoid *Ischiogonus syagrii* and the chalcidoid *Eupelmus* sp. The material on which the present study is based was not reared till 1929 and 1931 and nothing is known of the circumstances of its collection.

The weevil is known to attack the stems of many ferns including tree-ferns and bracken.

The parasite pupates in the skin of the host larva (note by L. Gallard).

PROCTOTRUPES SYAGRII, sp. nov.

Female. Shining black; legs including coxae all red, scape and pedicel pale and flagellum below pale, tegula pale.

Head, scutum and scutellum smooth, with fine pubescence; propleuron smooth, with a few fine, weak, irregular rugae at middle of anterior margin, otherwise glabrous laterally; mesopleuron all glabrous; parapsidal furrows distinct only anteriorly; propodeum rugoso-foveate over caudal half, anterior half with a strong median carina bordered by irregular foveae, laterad mostly glabrous; petiole very short; abdomen abruptly convex above from its base (in lateral view), ovipositor only about half as long as segment 2 of abdomen; forewing long, broad, slightly infuscated; pterostigma as wide as long, radial cell distinct, broadening at apical half; scape not quite as long as first funicle, pedicel quadrate, first funicle at least three times as long as wide, second subequal to first, succeeding segments decreasing, penultimate about one and a half times as long as wide, apical segment distinctly longer than scape.

Male. Legs all pale, scape and pedicel pale but flagellum all dark, tegula pale.

Similar to female but declivous portion of propodeum relatively larger and more coarsely and irregularly rugoso-foveate; antenna similar but funicle segments a little longer.

Types. Holotype ♀, allotype ♂ and 5 paratypes in the Entomology Branch Collection of the New South Wales Department of Agriculture. One paratype ♀ and one paratype ♂ in the C.S.I.R.O., Division of Entomology Museum.

Type Locality. Helensburgh, N.S.W. (3 ♀♀, 3 ♂♂) (July, 1931).

Locality records. New South Wales: Thirroul (23-i-1929, L. Gallard), 1 ♀; Coalcliff (23-i-1929, L. Gallard), 1 ♀; Coaldale (12-xi-1929), 1 ♂.

The glabrous propleuron without longitudinal rugae or sulci is most distinctive, as too are the completely pale legs. All other Australian species have some strong markings on the propleuron, and the legs are partly dark.

Reference.

Pemberton, C. E., 1921.—The Fern Weevil Parasite. Its life history and introduction to Hawaii. *The Hawaii. Plant Rec.*, 25: 196-201.

ESTIMATION OF PROTOZOAN POPULATIONS IN SOILS BY DIRECT MICROSCOPY.

By J. S. Bunt, Teaching Fellow in Microbiology, Microbiology Laboratory, University of Sydney, and Y. T. Tchan, Macleay Bacteriologist to the Society.

(Plate vi, B.)

[Read 27th July, 1955.]

Synopsis.

The present paper discusses briefly the need for a technique that will enable reliable estimations to be made of populations of protozoa in the soil. Such a technique is then described. Evidence in support of the method is included and a modification is explained, involving the use of the Gram stain, which enables more extensive information to be collected on the soil microflora.

Introduction.

It is a well-known fact that culture techniques for the estimation of microorganisms in soil give only a relative value because there is no universal medium which will allow the growth of all soil organisms. It is well known that this is also true of soil protozoa. The recent technique introduced by Singh (1946) is the least selective method but it is by no means able to give a total number of protozoa without selection, e.g. flagellates may not feed on bacteria (private communication by Dr. N. B. Singh). Direct microscopy is the logical method to overcome the selectivity of culture techniques. Most soil microorganisms can be estimated by direct microscopy—Conn (1918), Cholodny (1930), Winogradsky (1925), Thornton (1934), Jones-Mollison (1948), Strugger (1948), Rossi (1921), Blair (1945), Tchan (1953), Manniger and Vamos (1950), Vamos (1950). For protozoa there is no adequate technique. The use of the dark field microscope does not always allow a distinction to be made between protozoa and algae and motile bacteria. The presence of soil particles makes the use of dark field microscopy very difficult and, in some cases, impossible.

The staining techniques normally applied to the direct microscopy of soil are not adequate. Simple staining methods do not provide sufficient contrast for easy observation of soil protozoa at low magnifications. Further, the normally low numbers of protozoa in soil would render this type of technique quite inadequate. The technique described below provides a method suitable for the estimation of soil protozoa (Tchan and Bunt, 1954).

Technique.

Preparation of soil suspension.

Soil is suspended in a $^1/_{2000}$ solution of agar in the ratio 1 soil : 4 agar. If the bacterial population is also to be examined, the agar solution should be freed of bacteria by heating the solution with egg white in an autoclave and filtering on No. 1 paper. From this suspension a suitable series of tenfold dilutions is prepared with the same agar solution. It may be found necessary to use wide-mouthed pipettes for these manipulations to avoid blockages caused by large soil particles.

Preparation of slides.

From each dilution 0·1 c.c. is deposited on each of five clean slides. To prevent undue spread of suspension on the slides, it is recommended that the drops be placed in squares of a suitable dimension (e.g. 1·5 cm. × 1·5 cm.) drawn with a grease pencil on the glass. The slides are fixed in osmic acid or formalin vapour and then dried at 37°C. (about 45 minutes).

Staining technique.

(*a*) The soil slide is first flooded with erythrosin (1 part in 100 in 5% phenol) for 1–2 minutes. After gentle washing in running water it is counterstained with methyl green (0·1% aqueous solution) for a few seconds. Wash in water and dry in air. The preparation is then mounted in euparal or immersion oil for examination. The soil particles are stained green and the protozoa pink with purple nuclei. Flagella and cilia are pink and readily visible. Bacteria are purple. Fungal hyphae may be pink or purple. (Plate vi, B.)

(*b*) A variant of staining technique (*a*) allows the differentiation of Gram + and Gram – bacteria and protozoa in soil.

Since the Gram technique used has not been fully reported in the previous paper (Tchan, 1952), it is of interest to give some details here. The principle of using iodine-alcohol to avoid excessive differentiation is not new. The difficulty with soil preparations resides in the strong affinity of some soils for crystal violet, a prolonged washing with alcohol being required to remove the dye from soil colloids. It is necessary to use a well-defined iodine-alcohol solution which should enable a very efficient decolorization of soil colloids but not of Gram-positive microorganisms.

After several trials it was found that the formula used is most suitable. Some slides kept in the iodine-alcohol solution overnight still showed some Gram-positive organisms perfectly black. Usually the differentiation requires about 1–5 minutes to remove completely the crystal violet from the soil particles. However, it has been found that some soils require 10 minutes.

Some reputed Gram-variable bacteria, e.g. *Corynb. diphtheriae*, were found to remain Gram-positive after washing with iodine-alcohol. When the iodine concentration is too low or too high, the Gram-positive organisms may be decolorized or the Gram-negative organisms may remain black.

When applying the stain to agar films in the Jones and Mollison technique (1948), it is necessary to ensure that the agar film is perfectly dry. It is advisable to pass the slide over a flame for a few seconds and allow to cool before the staining process.

Technique (Tchan, 1952).

(1) Crystal violet 10 g., ammonium oxalate 4 g., 95% alcohol 100 c.c., water 400 c.c.
(2) Iodine 1 g., KI 2 g., 95% alcohol 25 c.c., water 100 c.c.
(3) Iodine solution as above 5 c.c. + alcohol 95% 95 c.c.
(4) Erythrosin 1 g., phenol 5 g., water 100 c.c.

The slide preparation is flooded by (1) for one minute, wash with tap water, stain one minute with iodine solution (2). Wash with iodine solution (3) until no more violet colour can be removed. Wash with water. Counterstain with erythrosin (4). Wash in water. Counterstain with methyl-green as in method (*a*) above.

The Gram + bacteria are blue or black, and Gram – bacteria purple (due to the combined colour of erythrosin and methyl-green). The other microorganisms are stained as in the method (*a*).

Counting technique.

Examine the slides with a 10× objective for large protozoa and 40× for small protozoa. If necessary, the 65× objective can be used for checking purposes. Count the number of slides containing protozoa (record presence or absence only) until the last dilution gives a negative result in all five slides. The number of protozoa is calculated from McGrady's probability tables (1948, see Calmette et al.).

Recovery tests.

With a culture of *Colpoda* sp. the number per unit volume of suspension was estimated first by fixing drops of the suspension on a slide in formalin vapour and counting the total number of protozoa before drying. After counting, the slides were allowed to dry and then stained with technique (*a*). The total numbers of protozoa in the drops were recounted. The results are summarized in Table 1.

The results show that very few cells were washed away during the staining process.

TABLE 1.
Recovery of Protozoa in Drops of Culture Stained by Technique (a).

Numbers of *Colpoda* sp. Before Drying.		Numbers of *Colpoda* sp. After Drying and Staining.	
Drop 1	.. 152	Drop 1 ..	.. 152
,, 2	.. 100	,, 2 ..	.. 90
,, 3	.. 124	,, 3 ..	.. 132

Three cultures of protozoa were mixed in water. Their respective numbers were estimated by hæmacytometer counts. A known volume of the suspension was added to a known weight of soil. The recovery from the soil suspension was made according to the technique. The results are summarized in Table 2.

TABLE 2
Recovery of Protozoa Introduced into a Soil.

	Calculated Number.			Recovery.			
Experiment No.	1	2	Mean.	1	2	3	Mean.
Ciliates	84	87	86	125	45	85	85
Amoebae ..	27	29	28	35	20	35	30
Rhizopods ..	6	17	12	15	10	5	10
Total ..	117	133	126	175	75	125	125

These results show that the presence of soil particles does not interfere with the counting technique.

TABLE 3.
Counts of Protozoa in Two Soil Types.

	Lucerne Broth.	Mannitol Soil Extract Agar.	Direct Microscopy.
(*a*) University Garden Loam.			
Ciliates	275	6250	1750
Flagellates	350	6250	4000
Amoebae	0	2380	1750
Rhizopods	0	0	350
Spores	0	0	5500
Total	625	14880	13350
(*b*) Macquarie Island Peat Soil.			
Ciliates	5	63	850
Flagellates	0	0	250
Amoebae	0	0	250
Rhizopods	0	0	120
Spores	0	0	4000
Total	5	63	5470

Experiments with soils.

Two types of soil were used—a garden loam from Sydney University and a sub-Antarctic peat from Macquarie Island. The protozoa numbers were estimated by the technique suggested and by inoculating a series of soil dilutions into (1) lucerne broth (100 g. finely ground lucerne chaff boiled in water for 30 minutes, filtered, and filtrate made up to one litre with tap water, pH adjusted to 7·0–7·2) and (2) mannitol soil extract agar (Allen, 1949).

The results, calculated from McGrady's tables, are summarized in Table 3.

Except in the case where University loam was inoculated into mannitol soil extract agar, greater numbers of protozoa were detected with direct microscopy than with several commonly employed culture techniques. This was especially noticeable with the soil from Macquarie Island. The differences in numerical distribution of the various groups shown by the different techniques is particularly striking.

Discussion.

Most staining techniques used for counting soil microorganisms by direct microscopy have been based on the fact that acid dyes do not stain soil colloids. This is satisfactory if a lens of high magnification is used. When lenses of low magnification are desirable, it is better to have a strong contrast between the background and the microorganisms. This chromatic property has been used in the Ziehl-Neelsen stain for the detection of *Mycob. tuberculosis* in sputum, using the advantage of a strong contrast between blue and red. To obtain the desirable contrast in the present technique a green-red combination was utilized, which is more restful during prolonged observation than blue-red. The background colour is obtained with methyl green. *A priori*, the use of a basic dye is not indicated for staining soil suspensions for counting the microflora. Erythrosin stains microorganisms red and this dye will be retained sufficiently to produce a pink colour provided the basic dye treatment is not prolonged. Since the cytoplasm of protozoa has a strong affinity for acid dyes, it is stained intensively by erythrosin. Methyl green is a basic dye which has an affinity for cell nuclei and soil particles. The nucleus is stained by erythrosin and methyl green so that it appears pink.

The Gram stain has the added advantage of securing extra information on the soil microflora. The Gram technique described can also be applied to Jones and Mollison's agar film technique for counting soil microorganisms. Since there is no heating, it does not damage the agar film. The method has advantages over Jensen's (1934) technique, which is more difficult to use and may damage the agar film when the heat treatment is applied.

The slides used must be perfectly clean and handled with care. Human skin cells may be found very commonly on slides if one does not take the precaution of avoiding the surfaces of the slides with one's fingers. However, such cells are readily recognizable and do not result in false positives being recorded.

The use of grease pencil for delimiting an area on the slide has two advantages: 1. The suspension will not run on the slide; 2. The edge of the preparation is well defined thus facilitating microscopic examination.

The use of agar fluid for suspending the soil particles is important. It fixes the protozoa strongly on the slide and eliminates the loss of cells during washing. With plain water, 90% losses occurred in some cases. Agar, in low concentration, does not solidify at room temperature and is straightforward to use in the preparation of soil dilutions. The viscosity of the fluid is higher than water and makes soil suspensions more homogeneous, so that often a better distribution of the contained protozoa results.

The present technique has been compared with other microscopic methods. Fluorescence microscopy using orange acridin is of no use (Strugger, 1948), as soil particles fluoresce red and are not in contrast with the protozoa. Dark field illumination is not suitable because of the degree of light reflection caused by the particles of

soil. The phase microscope is of little help with unstained preparations at low magnifications. With stained preparations the colour changes due to the phase arrangement suppress the contrast between green and red. Therefore it is not useful for counting purposes.

The recovery tests showed that with pure cultures a good recovery was obtained (Table 1). When a mixture of several pure cultures was added to a soil the recovery was reasonable (Table 2).

When the present technique was compared with culturing techniques (Table 3), it was found that a great number of protozoa which were missing in culture were estimated by the direct method. Also culture techniques involving pre-treatment of soil with acid do not provide a reliable estimate of the resting forms of protozoa which can be observed and counted by direct microscopy.*

The lowest theoretical number of protozoa which can be estimated in soil by this technique is 10 cells per gram. It is unlikely that such a small population would be of any significance. When the number reaches 100 or more there is no difficulty in obtaining a reliable count. Usually satisfactory agreement is obtained between duplicates.

Conclusions.

The technique described is a suitable method for the estimation of protozoan populations in soils. It has the advantage of providing a non-selective estimate of the groups making up the total population in any soil. The staining method is not limited to studies of protozoa. It may be used also for examining bacteria and fungi. When used in conjunction with the Gram stain it enables more detailed information to be collected on the soil microflora. For field experiments the slides can be prepared in the field and studied later in the laboratory without allowing any change in the protozoan population during transport.

Acknowledgements.

The writers are indebted to Associate Professor J. M. Vincent (Faculty of Agriculture) and Dr. B. N. Singh (Central Drug Research Institute, India) for criticism of the manuscript. They also wish to thank the Australian National Antarctic Research Expedition for the use of soil samples from Macquarie Island. We express our thanks to Miss G. L. Allpress for the typing of the manuscript.

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* Unfortunately it is not possible to differentiate the cysts of different protozoa, nor to identify with accuracy the different protozoa by the direct microscopy.

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EXPLANATION OF PLATE VI, B.

(*a*) Ciliate : Cilia are readily visible on the original print.

(*b*) Flagellate : The print is over-exposed to show the flagellum. Otherwise some internal structure would be visible.

(*c*) Amoebae.

(Photographs taken at an initial magnification of 270× and enlarged to 950× for reproduction.)

SYSTEMATIC STATUS OF A LEAF RUST ON *HORDEUM LEPORINUM* LINK IN AUSTRALIA.

By E. P. Baker and K. S. McWhirter, Faculty of Agriculture, The University of Sydney.

[Read 29th June, 1955.]

Synopsis.

A rust species, *Puccinia hordei* Fckl., occurring on *Hordeum leporinum* Link in the Hills district near Sydney, has been identified by morphological and pathological studies.

The nomenclature of this rust as *P. hordei* Fckl. conflicts with the current nomenclature of the dwarf leaf rust of barley, now known as *P. hordei* Otth.; the epithet *"hordei"* for the rust species on *H. leporinum* has priority. Buchwald's suggestion that this rust be relegated to subspecific status with the name *P. hordei-murini* is discussed. It is concluded that there is no evidence to support this suggestion and that the present confusion can be dispelled only by experimental studies with the alternate host plants.

Introduction.

Hordeum leporinum Link has frequently been reported as a host for various species of rust in Australia and other parts of the world. These have included the species *Puccinia graminis*, subspecies *avenae* E. & H. and *tritici* E. & H. (Waterhouse, 1952), *P. glumarum* (Schm.) E. & H. and *P. hordei* Fckl. (not *P. hordei* Otth.) (Straib, 1937; Arthur, 1934). In glasshouse tests Waterhouse (1929) listed the species as susceptible to *P. simplex* E. & H. (syn. *P. hordei* Otth.) and *P. triticina* Erikss. This was in contrast to an earlier report (Waterhouse, 1927) in which *H. murinum* L. was highly resistant to *P. anomala* Rostr. (syn. *P. hordei* Otth.). Other authors in Australia have reported *H. murinum* to be uniformly resistant to *P. hordei* Otth., the dwarf leaf rust of barley (Watson and Butler, 1948).[1]

A specific leaf rust on *H. murinum* (now almost certainly taxonomically *H. leporinum*) was first described by Fuckel in 1860 (Arthur, 1934; Cunningham, 1931). Straib (1937), on the basis of inoculation tests, showed this rust to be distinct from *P. dispersa* E. & H., *P. triticina* and *P. simplex* (syn. *P. hordei* Otth.). Buchwald (1943) and Arthur (1934) have emphasized that the rust *P. hordei* Fckl., is morphologically distinct from the rust *P. hordei* Otth., on cultivated barley.

Occurrence.

A specimen of *H. leporinum* bearing leaf rust was collected at Castle Hill Research Station in August, 1954. The systematic status of the plant was verified by the junior author. The plant had 14 pairs of chromosomes and is thus differentiated from the closely related *H. murinum* L. and *H. stebbinsii* Covas, each of which has seven pairs of chromosomes (Covas, 1949).

H. leporinum was not widespread at Castle Hill, but most plants were lightly infected with rust herein styled Acc. No. 54.40. The dark orange uredosori were mostly epiphyllous, occasionally on both leaf surfaces, scattered over the leaf blade, raised and opening by a narrow longitudinal slit in the epidermis. A mild epiphytotic of the disease was later observed in a dense stand of *H. leporinum* at a neighbouring centre, Baulkham Hills. In this material uredosori frequently occurred on the leaf sheaths, as well as laminae, and plants were severely damaged.

[1] The specific designation *H. murinum* L. was presumably used by Waterhouse (1927 and 1929) for *H. leporinum* Link on Covas' scheme (Covas, 1949) for the classification of the genus *Hordeum*, whilst Watson and Butler (1948) use the two specific names synonymously.

Inoculation tests with the rust collected at Castle Hill and morphological studies of the uredospores indicate that the rust closely resembles the form described by Fuckel (Arthur, 1934). A critical identification based on the teleutospores has not been possible, since these have not yet been observed.

Specialization and Host Range.

Seedlings and/or mature plant clones of the following grass species were inoculated with fresh uredospores taken from pustules developing on *H. leporinum* seedlings in the glasshouse; in no instance was there any indication of infection (infection type "O"):

Aegilops divaricata,[1] *Agrostis avenacea* Gmel., *A. tenuis* Sibth., *A. tenuis* var. *aristata* (Parnell) Druce, *Bromus mollis* L., *B. hordeaceus* L., *Cynodon dactylon* (L.) Pers. (seedlings and mature plants), *Danthonia semiannularis* (Labill.) R. Br., *Festuca rubra* L. var. *fallax* Hack., *Holcus lanatus* L. (mature plant), *Lolium perenne* L., *L. multiflorum* Lam., *L. rigidum* Gaud., *Lolium* sp. (N.Z. short rotation), *Poa pratensis* L., *Stipa aristiglumis* F. Muell., *S. verticillata* Nees.

No infection was observed on inoculated seedlings of Federation wheat, Black Winter rye, Algerian oats or Burke oats (infection type "O").

Three collections of *H. spontaneum* Koch. in the seedling stage gave a necrotic fleck reaction (infection type ";").

Seedlings of one collection of *H. bulbosum* L. and two of *H. marinum* Huds. gave a few necrotic flecks (infection type "O;").

The results of the remaining inoculation tests with species of *Hordeum* are given in Table 1. Approximately 30 seedlings from bulked progenies of each variety were tested in each case, except for *H. leporinum* collections from Newtown and Binnaway, N.S.W., where one single adult plant was tested in each instance and also where seedlings of single plant progenies of two collections of this species made in the University grounds were used. The tests were conducted during the early summer months in the glasshouse within a temperature range of 60°–80°F. approx.

Inoculation results indicate that the rust on *H. leporinum* does not conform to any of the more commonly occurring rusts in Australia. An occasional infection with a low reaction type was observed on cultivated barley, but the differentiation from the known races of *P. hordei* Otth. is evident from the low infection types on all varieties tested. Moreover, in reciprocal tests, *H. leporinum* showed only a few necrotic flecks when inoculated with UN (unified numeration) 16 and UN 14, the two races of *P. hordei* Otth. present in Australia, following the differential set of varieties and key used by Levine and Cherewick (1952).

The inoculation results on wheat, oats, and rye differentiate the rust from *P. triticina*, *P. coronata avenae* Erikss. and *P. dispersa*.

Morphology.

In morphological studies accession number 54.40 was compared with race UN 16, the common Australian race of *P. hordei* Otth. Uredospore measurements were made for 100 spores shaken on a slide from fully developed cultures of each rust and mounted in 50 per cent lactic acid. The results are given in Table 2.

Uredospores of the rust on *H. leporinum* are significantly smaller and lighter in colour than those of race UN 16 of *P. hordei* Otth.

Considering the rust identified on *H. leporinum* elsewhere, the uredospore measurements closely correspond to those given for *P. hordei* Fckl. by Arthur (1934), viz., "18–24 by 22–28μ". The ranges recorded for the present isolate were 18·8–23·2 by 21·8–29·0μ.

The shape of the uredospore was ellipsoid or slightly subovoid and the germ tubes were indistinct with probably three or more in a face.

The uredospore size is probably significantly different from that recorded for *P. glumarum* by Arthur (1934). The distribution of uredosori on the leaf may also

[1] Initially introduced from Cambridge, England, as *A. divaricata*, subsequently determined by Dr. A. E. Watkins to be *Triticum dicoccum* Schulb.

serve to distinguish *P. glumarum* from accession No. 50.40 on *H. leporinum*, as also do inoculation results with wheat, oats, rye, barley and *Bromus* species. In addition, the uredospore size and shape, coupled with inoculation results, indicate that the rust is probably distinct from any of the remaining rust species on graminaceous plants described by McAlpine (1906).

TABLE 1.

Results of Seedling Inoculation of Species of Hordeum *with Rust Accession S.U. 54.40.*

Species and Variety.	Infection Type.	Class of Reaction.
Hordeum leporinum—1[1]	4	Susceptible.
,, ,, —2[1]	4	,,
,, ,, [2]	4	,,
,, ,, [3]	4	,,
H. vulgare L. emend. Lam.[4]		
Smooth awn × Manchuria B36[5]	0	Immune.
No. 22 B69	0	,,
No. 49 B62	0	,,
Athos B125	0	,,
Cape B46	; 1^-	Very resistant.
H. distichum L. emend. Lam.		
Kinver B49	0	Immune.
Goldfoil B167	0	,,
Purple nudum C.I.2250 B28	; $1^=$ 1^-	Very resistant.
H. irregulare E. Åberg and Wiebe		
Abate—Red stem B308	; 1^- 1	Resistant.
Abyssinian intermediate B490	; $1^=$	Very resistant.

[1] Progeny of single plant selection, Sydney University.
[2] Adult plant, collected Newtown, Sydney.
[3] Adult plant, collected Binnaway, N.S.W.
[4] Classifications follow the system of E. Åberg and G. Wiebe (1946).
[5] Sydney University accession number.

On the basis of these results it seems reasonable to conclude, even in the absence of a study of the teleutospores, that the present rust on *H. leporinum* belongs to the species tentatively termed *P. hordei* Fckl.

TABLE 2.

Comparison of Studies with Two Rust Cultures.

Character.	*P. hordei* Otth. Race UN16 (Culture S.U. No. 62) from Barley.	Rust Accession 54.40 from *H. leporinum*.
Uredosori colour	Dragon's-blood Red[1]—Plate XIII.	Rufous—Plate XIV.
Uredospore colour (low power, full illumination)	Ochraceous-Orange—Plate XV.	Antimony Yellow—Plate XV.
Uredospore length ..	$26{\cdot}7 \pm 0{\cdot}16\mu$[2]	$24{\cdot}7 \pm 0{\cdot}15\mu$
Uredospore width ..	$23{\cdot}9 \pm 0{\cdot}14\mu$[2]	$21{\cdot}4 \pm 0{\cdot}1\mu$
Cytoplasm of uredospore ..	Aggregated along spore wall.	Aggregated in centre of spore.

[1] Ridgway's Color Standards (1912).
[2] Significantly different at P = 0·05.

SYSTEMATICS AND DISCUSSION.

So far as the authors are aware, there has been no previous record of the occurrence of *P. hordei* Fckl. on *H. leporinum* in this country. However, Professor W. L. Waterhouse recalls (personal communication) the examination of rust on *H. leporinum* which was

unable to produce infection on wheat, oats, rye or barley. This probably was the same species as that considered here, and it is not unlikely that the rust has been present in Australia for some time.

The systematic status of this rust, tentatively termed *Puccinia hordei* Fckl., has now to be considered. The use of the epithet "*hordei*" conflicts with the correct name of *P. hordei* Otth. for the dwarf leaf rust of barley. Use of the latter name dates from 1952, when Levine and Cherewick (1952) reviewed the nomenclature of this pathogen. Briefly, this can be summarized as follows.

Winter in 1884 classified the leaf rust on barley as *P. rubigo-vera* var. *simplex* Körnicke. Eriksson and Henning raised it to specific rank, with the name *P. simplex*, in 1894. However, this name was applied by Peck in 1881 to a different species and was moreover antedated by the name *P. anomala* published by Rostrup in 1878 (Cunningham, 1931). The name *P. hordei* Otth. was published in 1871, and Stevenson and Johnson (cited by Levine and Cherewick (1952)) give this name priority. Yet Cunningham (1931) states that this name could not be used since it was applied by Fuckel in 1860 to a "different and valid species".

Buchwald (1943) resolved this conflict by relegating the rust on *H. murinum* described by Fuckel to subspecific status with the name *P. hordei-murini*. This would require that the rusts on cultivated barley and wild barley grasses should have a common alternate host plant. Buchwald based this contention on the apparently faulty evidence that "*P. hordei* Fckl. 1873 is a homonym of *P. hordei* Otth. 1871". The *P. hordei* of Fuckel was described in 1860 (Fuckel, 1860, cited by Arthur, 1934). No reference to the aecidial stage of either rust was made.

Obviously the conflicting nomenclature of these rusts can be corrected only by experimental studies with the alternate host plants. The aecidial stage of *P. hordei* Fckl. is not yet known (Arthur, 1934). The aecidial stage of *P. hordei* Otth. has been produced on *Ornithogalum umbellatum* L., *O. narbonense* L., *O. pyrenaicum* L., and on *Dipcadi serotinum* (L.) Medic. (d'Oliveira, 1939; Mains and Jackson, 1924; Mains, 1930; Dennis and Sandwith, 1948; d'Oliveira, 1949; and Levine and Cherewick, 1952) in Europe and North America. In Australia the teleutospores could not be germinated and the natural occurrence of the aecidial stage has not been observed (Waterhouse, 1952). This will need to be done if the nomenclature of these rusts is to be lifted above the present level of confusion.

It is concluded from the above review that the name "*P. hordei*" for the rust on *H. leporinum* has priority and the ultimate retention of *P. hordei* Otth. for the dwarf leaf rust of barley will require the verification of *P. hordei-murini* (Fckl.) Buch. as a valid subspecies.

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DISEASES OF RICE IN AUSTRALIA.

By P. G. Valder, Biological Branch, New South Wales Department of Agriculture.

(Plate vi, A; one Text-figure.)

[Read 27th July, 1955.]

Synopsis.

Apart from downy mildew (*Sclerospora macrospora* L.), which has not been recorded for many years, no parasitic diseases of rice are known in New South Wales. In this paper the occurrence is reported in northern Australia of leaf smut (*Entyloma oryzae* H. & P. Syd.) on *Oryza australiensis* Domin and *O. sativa* L. (wild and cultivated forms), brown spot (*Helminthosporium oryzae* Breda de Haan) on *O. australiensis* and *O. sativa* (wild form), and blast (*Piricularia oryzae* Cav.) on *O. sativa* (cultivated forms). Other fungi of minor importance are also recorded.

Diseases Recorded in New South Wales.

Apart from an old record (Noble et al., 1934) of downy mildew (*Sclerospora macrospora* Sacc.), there have not been any records of parasitic diseases of rice in New South Wales. Downy mildew has not been observed for many years and it may well be that the fungus concerned was *S. oryzae* Brizi. Padwick (1950) supports the view that this fungus is restricted to rice and is morphologically distinct from *S. macrospora*. Unfortunately herbarium specimens have not been located and the identity of the fungus remains in doubt.

In New South Wales rice is grown in two inland districts under irrigation. The climate is semi-arid and no doubt this is partly responsible for the absence of diseases caused by pathogens. However, a number of non-parasitic disorders occur, of which one of the most frequently observed is a purplish-brown pigmentation of areas of glumes and leaves. This seems to be a characteristic of the varieties concerned and has no apparent detrimental effect. A brown discoloration of the caryopses is also of common occurrence and in all the specimens examined has been associated with the presence of *Alternaria* spp. of the *A. tenuis* type. These fungi have been consistently isolated from such grains and from pieces of discoloured pericarp. Microscopical examinations have demonstrated the presence of dark hyphae within the pericarp but not penetrating the endosperm. Such hyphae are rare within the pericarps of grains of normal appearance and the condition seems analogous with black point or smudge of wheat (Shaw and Valder, 1952). Germination tests in soil and on moist filter paper have not yielded any diseased seedlings either from discoloured or apparently normal grains.

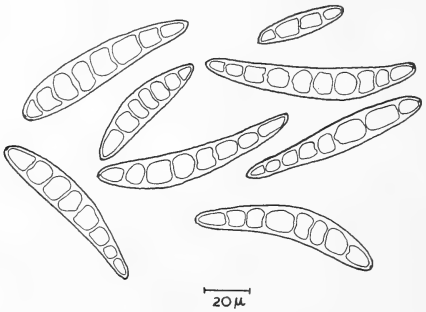
A species of *Phoma* has been noticed on bleached areas of the glumes and, although no investigations have been carried out, the appearance of the affected areas suggests that the fungus is of doubtful or weak pathogenicity. There have been instances overseas where similar fungi have been reported to have caused appreciable damage (Padwick, 1950).

Another commonly occurring condition has been described as a "blasting of the spikelets with release of starch grains". This has been found to be a mechanical injury caused by finches, which snap at the spikelets when the grain is in the "milk ripe" condition. Such spikelets frequently become overgrown with moulds, predominant amongst which is *Cladosporium herbarum* Link ex Fr.

Diseases Recorded in Northern Australia.

A number of rice diseases have been recorded recently in northern Australia, where cultivated varieties are being grown experimentally in several localities. Australian rice (*Oryza australiensis* Domin) and wild rice (a form of *O. sativa* L.) occur here naturally.

In 1953, at the invitation of the Commonwealth Director of Plant Quarantine, a visit was made by the author to northern Australia for the purpose of examining the rice disease position, and as a result a number of additional records was made. Further observations may well reveal the presence of other diseases.



Text-fig. 1.—Conidia of *Helminthosporium oryzae* from a leaf of *Oryza sativa* (wild form) collected on Humpty Doo Station, Northern Territory.

The diseases so far known to occur in northern Australia are as follows:

Leaf Smut: The recorded occurrence of Leaf Smut (*Entyloma oryzae* H. & P. Syd.) is shown in Table 1. This fungus is not considered to cause noticeable losses and is regarded by Zundel (1939) as synonymous with *E. lineatum* (Cke.) J. J. Davis, a smut occurring on *Zizania aquatica* L.

TABLE 1.

Records of the Occurrence of Entyloma oryzae *H. & P. Syd. in Australia.*

Date.	Locality.	Host.	Collector.
March, 1951 ..	Kimberley Research Station, Ord River, W.A.	*Oryza sativa* L.	L. C. Lee.
February, 1952 ..	Lower Ord River, W.A.	*O. australiensis* Domin.	L. C. Lee.
March, 1953 ..	Lower Ord River, W.A.	*O. australiensis* Domin.	P. G. Valder.
March, 1953 ..	Kimberley Research Station, Ord River, W.A.	*O. sativa* L.	P. G. Valder.
March, 1953 ..	Humpty Doo Station, N.T.	*O. sativa* L.	P. G. Valder.
March, 1953 ..	Humpty Doo Station, N.T.	*O. sativa* L. (wild form).	P. G. Valder.

The fungus and the disease, which has a characteristic appearance, are well described by Padwick (1950). On *O. australiensis* the sori are inclined to be confluent and frequently appear longer than they do on *O. sativa*.

Brown Spot: Records of the occurrence of brown spot (*Helminthosporium oryzae* Breda de Haan) are set out in Table 2. At the time of the author's visit the disease was very common on *O. australiensis* and on the wild form of *O. sativa*, which was growing abundantly in and around the experimental plots in the Northern Territory. Only the leaf spot phase of the disease was present. The symptoms and the morphology of the fungus agree closely with the descriptions set out by Drechsler (1923) and by Padwick (1950), who summarizes the literature. The fungus was also easily identified using Luttrell's (1951) key. Leaves of *O. australiensis* with young lesions are shown in Plate vi, A, fig. 1.

Conidia from leaves collected in the field measured 10–17μ × 12–115μ with up to nine septa. Little reliance, however, can be placed on spore measurements alone as a diagnostic characteristic, as the conidial dimensions of species of *Helminthosporium* are notoriously variable, both between isolates of the one species and between conidia of the one isolate produced under different conditions. Those of *H. oryzae* are usually widest about one-third of the distance from the base, and Australian isolates show an inconspicuous hilum within the contour of the base (Text-fig. 1).

Although there was considerable variation in the cultural characteristics of the different isolates, they agreed closely in morphology and in host range as determined in glasshouse tests, whether they were isolated from *O. sativa* or *O. australiensis*. They also agreed with isolates obtained from a seed sample imported from Malaya and all proved to be capable of infecting "Federation" wheat, "Skinless" barley, "Vicland" oats, "Dawn Hybrid" maize, "Kalo" sorghum, "Caloro", "Blue Bonnet" and "Rexoro" rice and *Cynodon dactylon* (L.) Pers. but not *Pennisetum clandestinum* Hochst. Padwick (1950) states that many workers have noted the wide host range on cereals and grasses of *H. oryzae* under laboratory conditions. He considers that the resistance of grasses to species of *Helminthosporium* is relative only and can be broken down by presenting an abundance of inoculum and ideal conditions for infection. This has been found to be largely true also for various species isolated from grasses in New South Wales and it will be interesting to see whether the *H. oryzae* present on the wild rices in northern Australia will attack cultivated varieties in the field.

TABLE 2.

Records of the Occurrence of Helminthosporium oryzae *Breda de Haan in Australia.*

Date.	Locality.	Host.	Collector.
March, 1952 ..	Lower Ord River, W.A.	*O. australiensis* Domin.	L. C. Lee.
March, 1953 ..	Lower Ord River, W.A.	*O. australiensis* Domin.	P. G. Valder.
March, 1953 ..	Humpty Doo Station, N.T.	*O. sativa* L. (wild form).	P. G. Valder.

Padwick (1950) could find no record of natural infection of any host other than *O. sativa* except *O. montana* from Togo. This record was made by Roger (1935), who did not give an authority for the name, although the Director, Royal Botanic Gardens, Kew, states, in a personal communication, that it is very probable that *O. montana* Lour., which is now regarded as a form of *O. sativa*, was intended. If this is the case, the record of the natural occurrence of *H. oryzae* on *Leersia hexandra* Sw., a grass present in Australia, in India by Chattopadhyay and Chakraborti (1953) is the first on a host other than *O. sativa* and that on *O. australiensis* the second. It is not yet known whether the perfect stage, *Cochliobolus miyabeanus* (Ito & Kurib.) Drechs. ex Dastur, occurs in Australia.

Rice blast: Early in 1954 leaves of cultivated varieties from the experimental areas near Darwin were forwarded by Mr. W. Stahl, of the Department of Territories. These were carrying lesions caused by the blast fungus (*Piricularia oryzae* Cav.) (Plate vi, A, fig. 2). This disease had been reported previously from an experimental plot in Queensland in 1950. The fungus was isolated and shown to be capable of infecting "Magnolia" rice. The literature concerning the disease is summarized by Padwick (1950).

Other diseases:

Curvularia spp. and *Nigrospora oryzae* (Berk. & Br.) Petch are ubiquitous on dead tissues of rice in northern Australia, sometimes being associated with minute leaf spots and discoloured grains. *Phoma* spp. have also been observed. Although most of the *Curvularia* isolates are close to *C. lunata* (Wakk.) Boed. or *C. maculans* (Bancroft) Boed., there is considerable variation and many seem to be intermediate between these and other species. In glasshouse tests *Curvularia* spp. and *Nigrospora oryzae* have

produced small lesions on "Caloro". Seed rice produced near Darwin, when germinated at 30°C. on moist filter paper and in soil, gave rise to a number of seedlings with brown lesions on the coleoptiles from which *Curvularia* spp. were isolated. The subsequent development of such seedlings, however, was unaffected and it seems likely that, apart from their ability to discolour the grain, these fungi are of little importance. Cralley and Tullis (1937) and Mundkur (1946), however, credit *Curvularia* spp. with considerable virulence.

Hence it appears that while, apart from saprophytic or weakly parasitic fungi causing discolorations, there are at the present time no parasitic diseases known on rice in New South Wales, several such diseases have been observed already on wild and cultivated rice in northern Australia and, should rice growing become established in that area, there may be disease problems from which the industry in New South Wales is fortunately free.

Acknowledgements.

Sincere thanks are extended to Dr. T. H. Harrison, Director of Plant Quarantine, for arranging the visit to northern Australia, and to Miss J. W. Vickery, National Herbarium, Sydney, for identifying the wild rice specimens.

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EXPLANATION OF PLATE VI, A.

1. Leaves of *Oryza australiensis* showing young lesions of brown spot (*Helminthosporium oryzae*).

2. Leaves of *Oryza sativa* showing lesions of rice blast (*Piricularia oryzae*).

SOME AUSTRALASIAN MOSQUITOES (DIPTERA, CULICIDAE) OF THE SUBGENERA *PSEUDOSKUSEA* AND *NEOCULEX*.

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Elizabeth N. Marks, Department of Entomology, University of Queensland.

(Eight Text-figures.)

[Read 27th July, 1955.]

Synopsis.

The type series of *Culex australis* Erichson is redescribed as *Aëdes* (*Pseudoskusea*) *australis* (Erichson), with which *Aëdes* (*Pseudoskusea*) *crucians* (Walker) and *Aëdes* (*Pseudoskusea*) *concolor* (Taylor) are regarded as synonymous. The type of *Aëdes* (*Pseudoskusea*) *cairnsensis* (Taylor) is shown to be a species of *Culex*. Both sexes, pupa and larva of *Culex* (*Neoculex*) *cheesmanae*, n. sp., from New Caledonia are described and figured, and the male terminalia of *Culex* (*Neoculex*) *tricuspis* Edwards figured. The male, pupa and larva of *Culex chaetoventralis* (Theobald) are described and figured for the first time; characters of the male show that this species should be placed in the subgenus *Neoculex*. The relationships of the various species are discussed.

Aëdes (Pseudoskusea) australis (Erichson).

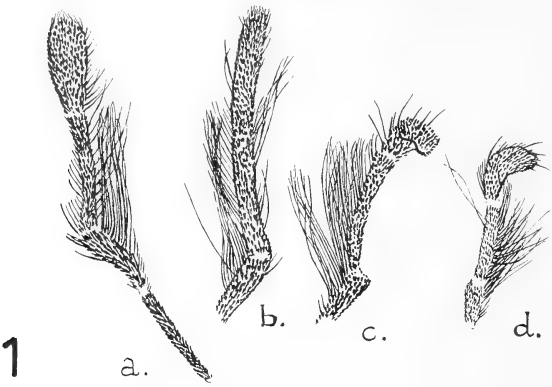
Culex australis Erichson, *Arch. Naturgesch.*, 8: 270, 1842. *Culex crucians* Walker, *Ins. Saund. Dipt.*, 1: 432, 1856. *Aëdes* (*Pseudoskusea*) *crucians* Edwards, *Bull. ent. Res.*, 14: 387, 1924. *Culicada tasmaniensis* Strickland, *Entomologist*, 44: 181, 1911. *Caenocephalus concolor* Taylor, *Trans. ent. Soc. Lond.*, 46: 700, 1914. *Aëdes* (*Pseudoskusea*) *concolor* Edwards, *Bull. ent. Res.*, 14: 387, 1924; 17: 113, 1926.

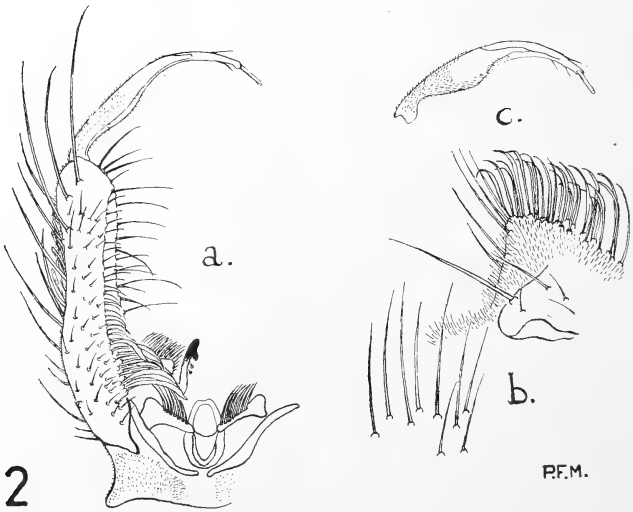
Theobald (1901) queried whether *C. crucians* might be a synonym of *C. australis*, but the specimens on which he based his redescription of *australis* were a different species (*Aëdes* (*Ochlerotatus*) *nivalis* Edwards, 1926). Edwards (1932) placed *C. australis* provisionally in the synonymy of *Tripteroides* (*Mimeteomyia*) *tasmaniensis* (Strickland) despite the fact that Erichson's description of the abdominal markings and the measurements of size which he gives are inconsistent with such an attribution. Through the kindness of Professor Dr. Fritz Peus one of us (P.F.M.) has been able to borrow the type series of three specimens left by Erichson in the Zoologisches Museum der Universitat in Berlin. It thus becomes possible to make a more convincing attribution and at the same time to describe and figure the type series and to mark lectotypes. Erichson's original description is brief and can be quoted in full. It runs as follows:

"245. *Culex australis.* Testaceus, thorace dorso fusco, abdomine nigro-fasciato, femoribus tibiisque summo apice pallidis. Long. corp. 3½., haustell. 2 lin.

"Antennae luteae. Haustellum sat elongatum, palpis maris hoc paulo brevioribus. Caput fusco-testaceum. Thorax dorso fuscus, lateribus et infra testaceus. Abdomen griseo-pilosum, segmentis basi pallidis, apice nigris. Pedes fusco-testacei, femoribus tibiisque summo apice albidis. Alae hyalinae, nervis testaceis, anterioribus fusco-villosis."

No doubt appears to exist regarding the identity of the type series, which comprises one female and two male adults. One male has the head missing. This has been marked as a paratype and the other as the hololectotype. The female has been marked as the allolectotype. The hololectotype bears the number 5986 and the series is accompanied by two labels, not individually attached, bearing the data "Terr. Van Diem. Schayer" and "australis Er." respectively. The whole series will be returned to the Berlin Museum. A description of it follows.





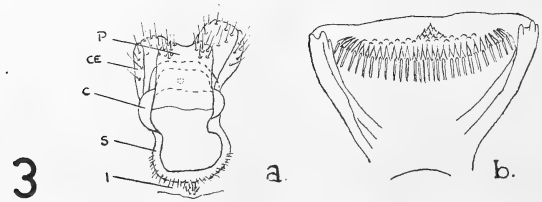


Fig. 1.—*Aëdes* (*Pseudoskusea*) *australis* (Erichson). Male palps. *a.* Type ♂. *b.* Type ♂ of *Aë. crucians* (Wk.). *c.* ♂ of *Aë. crucians* from Port Davey area. *d.* ♂ of *Aë. concolor* (Taylor) from Sydney.

Fig. 2.—*Aëdes* (*Pseudoskusea*) *australis* (Erichson). *a.* Terminalia of type ♂ in tergal view. *b.* The same in sternal view. *c.* Style of *Aëdes concolor* from Sydney showing unfurling.

Fig. 3.—*Culex cheesmanae*, n. sp. Female. *a.* Terminalia. *b.* Pharynx. *C.* Cowl. *CE.* Cercus. *I.* Insula. *P.* Post-genital plate. *S.* Sigma.

Adult ♂. The specimens are very old, faded, discoloured and in some places denuded. Characters other than structural characters are thus difficult to interpret. *Head*: proboscis mainly dark brownish but with a diffuse yellowish ring at about half-way and some scattered pale scales on both upper and lower surface anteriorly and posteriorly to this. Palps (Fig. 1) dark, about four-fifths the length of the proboscis, their apices swollen, clavate, flattened. Faint indications of pale scaling present at the articulations, especially the terminal one. Clypeus, antennal flagellum and torus apparently devoid of scales. Vertex largely covered with narrow, curved, golden scales. Upright scales golden-brown towards the front, the more posterior ones smaller and black. Broad, flat, yellow scales at sides of head. *Thorax* largely desquamated. Anterior pronotum with broad yellowish scales. Posterior pronotum with broad, flat, dark scales. Similar scales, mixed with broad whitish ones on postspiracular area and sternopleuron. Prealar scales present just below the knob of the latter. Mesepimeron with numerous broad, whitish scales and with a row of four stout lower mesepimeral bristles rather high up near the anterior edge. Scutum and scutellum with narrow, curved, golden and narrow, curved, dark scales. *Wings* apparently entirely dark, length about 5 mm. Knob of halteres appearing mainly dark but with a spot of pale scales. *Legs*: Front femur about two-thirds the length of the proboscis, pale below nearly to tip with a very small knee-spot. Front tibia dark except for a small apical pale patch. First front tarsal largely desquamated, others missing. Mid-femur and tibia similar to those of the front leg. Mid-tarsi dark, the claws unequal, the larger with two teeth, the smaller with one. Hind femur, tibia and first three tarsals apparently much as for the more anterior legs. Last two hind tarsals missing. *Abdomen*: Tergites with very broad whitish basal bands. Sternites mainly pale with small apicolateral spots of dark scales. *Terminalia* (Fig. 2): Style slender, curved, tapering with a more or less pronounced bulge before half-way, pilose towards the base. Terminal appendage cylindrical with cleft and slightly flared tip. Coxite long and narrow with scales on the outer surface, incompletely divided into tergal and sternal flaps, the former with numerous foliate setae on its inner edge towards the base, these becoming smaller and passing into small, curved, unmodified setae anteriorly. The inner edge of the sternal flap has a row of long unmodified setae of which the most basal is longer than its immediate neighbours and therefore conspicuous (Fig. 2*b*). Basal lobe of coxite densely pilose and with numerous somewhat flattened, recurved setae. Phallosome simple, membranous. Paraprocts (Xth sternites) with strongly sclerotized, hooked apices and each with two microsetae. Lobes of IXth tergite pyramidal, each with about seven strong setae on the inner face. IXth sternite membranous with a median group of nine long, stout setae.

Adult ♀. Proboscis appearing paler on about the basal two-thirds. Palps very short, about one-tenth the length of the proboscis or rather less. Torus and first segment of antennal flagellum with small pale scales. Front femur about three-quarters the length of the proboscis. Front and hind claws missing. Mid-claws subequal, each with a single large tooth. Otherwise much as in the ♂.

Save for the appearance of rather extensive pale scaling on the proboscis, the type series of *Aëdes australis* agrees well in its colour characters with the types and other specimens of *Aëdes crucians* and the series of *Aëdes concolor* in the British Museum. The appearance of pale scaling on the proboscis appears to have been exaggerated by fading and it is perhaps significant that Erichson did not mention it in his description. Nevertheless a definite, though less exaggerated, tendency of the same kind is to be observed in some specimens of *Aëdes tasmaniensis* in the British Museum. This is also implied in Strickland's description of this form, where he described the proboscis as "darker at the apex than at the base". By analogy with certain species of the related subgenus *Ochlerotatus* this seems likely to be a variable character. The type of *Aëdes crucians* is now reduced to thorax, abdomen, wings, and hind femur and tibia, so that a useful comparison is scarcely possible. However, none of these structures shows any characters which are at variance with the inclusion of *crucians* in the present synonymy. Edwards (1924, 1926) based his suggestion that *Aë. crucians* and

Aë. concolor should be treated as separate species on the following differences: 1, smaller size of *Aë. concolor*; 2, the swollen last segment of the male palps of this species; 3, its less swollen male style.

One of us (E.N.M.) while collecting in the Port Davey area of Tasmania found it possible to obtain intergrading series from different localities of all sizes from *concolor* up to full-sized *crucians* (wing length of ♀, 4·7–6·2 mm.). The larvae were indistinguishable from those of *Aë. concolor*, descriptions of which can be found in Woodhill and Pasfield (1941) and in Lee (1944). Despite their size the terminalia of the larger specimens appeared to be identical with those of *Aë. concolor*. In all cases except one the male palps were of the *Aë. concolor* type. In this specimen, which was pinned very shortly after emergence, the terminal segment failed to expand and instead retained the appearance considered by Edwards to characterize *Aë. crucians*. The term "swollen" as applied by Edwards to the male style is misleading, since this is not a solid object, but, like many structures in the terminalia of mosquitoes, an incompletely closed integumental tube. The appearance of increased swelling can be produced by rotation of the style into the position in which its greatest breadth is exhibited and by a slight unfurling during manipulation in a viscous mounting medium (Fig. 2*c*). In the light of this evidence we are no longer prepared to follow Edwards in treating these species as distinct. Instead, we prefer to synonymize them.

Distribution: Widely distributed along the south-east coast of Australia. The northernmost record is Fingal, N.S.W., about 10 miles south of the Queensland border (J. L. Wassell, 29:xi:1943). New Tasmanian records are South Arm (17:v:1953, E. G. Connah); Blackman's Bay (6:ii:1954, E. G. Connah); Port Davey area: Bond Bay, Coffin Creek, and coast near Trumpeter I. (—:ii:1954, E. N. Marks); Fisher I., off Flinders I., Bass Strait (22:xi:1952, J. H. Calaby and D. L. McIntosh). Lee (1944) records *Aë. concolor* from Norfolk I. Carter (1920) mentions five ♀♀ of a "probably undescribed species of *Ochlerotatus*" from Lord Howe I., captured by Mr. Laurie in a dwelling house. These specimens were loaned by the Liverpool School of Tropical Medicine to the British Museum, and represent a species of *Aëdes* (*Pseudoskusea*) closely allied to, if not identical with, *Aë. australis*, but males would be needed to determine whether they are conspecific.

Aëdes (Pseudoskusea) cairnsensis (Taylor).

Pseudoskusea cairnsensis Taylor, Proc. Linn. Soc. N.S.W., 43: 829, 1919. *Aëdes* (*Pseudoskusea*?) *cairnsensis* Edwards, *Bull. ent. Res.*, 14: 387, 1924.

The type ♀, in the collection of the School of Public Health and Tropical Medicine, Sydney, is not an *Aëdes* but a *Culex*, probably of the subgenus *Lophoceraomyia*. Determination of its identity must await a revision of the Australian species of that subgenus.

Culex (Neoculex) cheesmanae, n. sp.

Culex (*Neoculex*) *pseudomelanoconia* Williams (*nec* Theobald), *Hawaii Plant. Rec.*, 47: 217, 1943. *Culex* (*Neoculex*) *pseudomelanoconia* Laird (*nec* Theobald), *Bull. ent. Res.*, 45: 286, 1954.

This species is named in honour of Miss Evelyn Cheesman who, as a collector, has made notable contributions to our knowledge of the mosquitoes of the Australian Region and to whom we are indebted for part of the material here described.

The description is based on holotype ♂, allotype ♀, one paratype ♂, two paratype ♀♀ and six whole larvae, also marked as paratypes, from Nassirah, near Boulouparis, 50–60 miles north of Noumea, New Caledonia, —:viii:1954, bred out by Dr. M. O. T. Iyengar from "rock pools in river" and seven paratype ♂♂, five paratype ♀♀, one pupal pelt, two whole pupae and six whole larvae (paratypes) from Pueblo, near coast, 1500 ft., New Caledonia, —:ix:1949, bred out by Miss L. E. Cheesman from "rock-basins in midstream". Types and paratypes in the British Museum collection; two male, two female and two larval paratypes in the University of Queensland collection.

Adult ♂. A very small, jet black mosquito. *Head*: Palps and proboscis black, the palps almost exactly equal in length to the proboscis, excluding the labella, the proboscis slightly swollen distally and somewhat darker in this region than towards

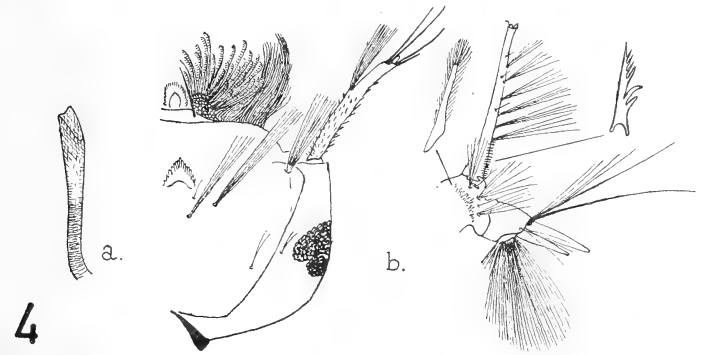
the base. Palps with long, stout black hairs at apices of third and fifth segments, some shorter hairs on fourth and fifth segments and a few very short ones on the third segment and the distal half of the second. Torus black, this and the first flagellar segment apparently devoid of scales. Vertex with narrow, curved white decumbent scales and narrow dark upright ones. Broad, flat white scales confined to two small lateral patches in the occipital region which show no tendency to extend onto the vertex. *Thorax*: Anterior pronotum with a few very fine, pale hair-like scales or bristles. Posterior pronotum bare of scales, with numerous fine dark hairs in front of the bristles. Scutum clothed with narrow, rather scanty brown scales with bronze reflection. Some of these scales appear lighter than others, but there is no definite pattern. Scutellum with similar scales apparently confined to the mid-lobe. Postnotum bare. Acrostichal and dorsocentral bristles very strongly developed. Pleura with integument blackish, as in the case of the scutum. Prealar and postspiracular scales absent, some fine pale hairs on postspiracular area. Sternopleuron with an extensive posteromedian patch of moderately broad whitish scales and pale hairs and bristles. Mesepimeron devoid of scales but with an extensive patch of fine pale hairs covering most of the upper three-quarters. Lower mesepimeral bristle absent. *Wings*: dark, length a little less than 2·5 mm. Plume scales narrow and very numerous. Upper (anterior) fork cell 1·8–3·0 times the length of its stem. Lower (posterior) 1·0–1·5 times the length of its stem. Knob of halteres dark, their stems pale on the lower, dark on the upper surface. *Legs*: Coxae with pale scales, some dark ones on the front coxae. Front femur slightly shorter than the proboscis. All femora pale below nearly to tip but with extreme apex dark. On the hind femur the pale ventral line extends onto the anterior surface as a broad stripe ending abruptly just before the apex. Posterior surface similar. On both surfaces the pale stripe tapers somewhat towards the apex, the tapering rather more pronounced on the posterior surface. Anterior claw of front leg larger than the posterior claw, the former with a strongly developed tooth near the middle, the latter with a much smaller tooth towards the base. Mid-claws similar but with the discrepancy in size between anterior and posterior greater. Hind claws small, equal, simple. *Abdomen*: Tergites and sternites entirely black, without pale scales. All segments with very numerous long setae giving an unusually hairy appearance. First tergite devoid of scales. *Terminalia* (Fig. 5*a*): Style stout, only slightly curved, swelling slightly to a point just before the tip, beyond which it narrows abruptly. Preapical crest strongly developed. Two setulae arising on the distal half. Terminal appendage short, pointed. Coxite not abnormally swollen, narrowing somewhat beyond the proximal portion of the subapical lobe. Subapical lobe in two widely separate portions of which the more distal bears three delicately fringed setae, a short, unmodified seta, a very narrow leaflet and a slender seta with hooked tip. This portion of the lobe is accompanied, as usual, by a long, straight, detached seta. Proximal portion with two long, ligulate setae with recurved tips, separated from the distal portion by an irregular double row of about ten short, stout setae with sinuous tips. Lateral plates of phallosome with the tips hooked but without teeth or tubercles, joined by a narrow, partly sclerotized bridge unusually near the tips. Paraprocts with all teeth relatively broad and blunt, without sub-basal arm. Xth tergites lightly sclerotized, as is usual in this subgenus, with rather numerous microsetae near their point of attachment. Lobes of IXth tergite scarcely detectable, without setae.

Adult ♀. *Head*: Palps about one-sixth the length of the proboscis. *Wings*: Length about 2·5–3·0 mm. Upper fork cell about 2·2–2·7 times the length of its stem. Lower fork cell about 1·0–2·0 times the length of its stem. *Legs*: Tarsal claws all small, subequal, simple. *Terminalia* (Fig. 3*a*): The terms used in the following description are those of Edwards (1941) (for an alternative nomenclature, *see* Coher (1949)). Cerci very broad, bluntly rounded. Postgenital plate distinctly bilobed. No atrial plates seen. Insula with a small but distinct circular patch of setulae. IXth tergite not seen, apparently unsclerotized and without setae as in the ♂. Spermathecae three in number, oboval. *Pharynx* (Fig. 3*b*): Teeth of lower row sharply pointed, those of upper row

difficult to distinguish, apparently blunt. Six teeth in the middle narrower and somewhat longer than the remainder. Lateral and ventral flaps normal for the subgenus.

Pupa. The nomenclature employed in the following description is that of Belkin (1952, 1953, 1954). *Cephalothorax*: Trumpet (Fig. 4*a*) long, slender. Meatus about four-fifths of greatest length. The available material is in poor condition and it is therefore impossible to gain very much idea of the extent of variation in chaetotaxy. Seta 1 long, stout, single; 2 of moderate length, slender, pentafid; 3 and 4 of moderate length, slender, trifid; 5 long, moderately stout, heptafid; 6 short, slender, apparently bifid; 7 long, slender, trifid; 8 long, moderately stout, apparently bifid, lightly plumose; 9 missing. *Metanotum*: Seta 10 of moderate length, slender, trifid to pentafid; 11 long, stout, single, plumose; 12 of moderate length, slender, bifid to tetrafid. *Abdomen*: Segment I with seta 1 dendroid, as usual, strongly developed with numerous branches which are further subdivided; 2 short, single; 3 long, stout, single, plumose; 4 short, tetrafid; 5 short, bifid to pentafid; 6 of moderate length, single; 7 minute, single; 10 minute, trifid. Segment II with seta 1 dendroid, a rather unusual condition, with numerous branches which are further subdivided; 2 minute, single; 3 of moderate length, single; 4 short, bifid; 5 long, slender, bifid or trifid; 6 long, stout, single; 7 minute, single; 10 minute, bifid. Segment III with seta 1 of moderate length, slender, apparently with about 8 or 9 branches; 2 minute, single; 3 long, stout, single; 4 short, single; 5 long, slender, bifid or trifid; 6 missing; 7 to 12 not seen. Segment IV with seta 1 of moderate length, slender, apparently with about six branches; 2 minute, single; 3 of moderate length, slender, bifid or trifid; 4 short, single; 5 long, stout, bifid or trifid; 6 long, slender, single; 7 minute, single; 8 short, single to trifid; 10 short, single or bifid; 11 not seen; 12 of moderate length, single or bifid. Segment V with seta 1 of moderate length, apparently with about four branches; 2 minute, single; 3 of moderate length, bifid; 4 short, bifid or trifid; 5 missing; 6 of moderate length, single; 7 minute, single; 8 short, single or bifid; 10 short, trifid; 11 minute, single; 12 not seen. Segment VI with seta 1 of moderate length, apparently with about four branches; 2 minute, single; 3 of moderate length, single; 4 of moderate length, bifid; 5 long, stout, trifid; 6 long, slender, single or bifid; 7 minute, single; 8 short, single; 10 long, slender, single; 11 not seen; 12 long, slender, single. Segment VII with seta 1 short, slender, trifid or tetrafid; 2 minute, single; 3 of moderate length, bifid; 4 long, slender, single; 5 short, bifid; 6 short, single to trifid; 7 of moderate length, stout with 5–6 plumose branches; 8 short, bifid or trifid; 10 short, bifid; 11 minute, single; 12 moderate to long, single and plumose or bifid and simple. Segment VIII with seta 5 missing; 7 short, stout, with four plumose branches. Paddles largely destroyed. Dorsal sensillum present near seta 4 on segments III–V. Seta 0 present on segments II–VIII. Seta 14 present on segments IV–VIII, not seen on III.

Larva (Fig. 4*b*). This has been described and figured from New Caledonian material by Williams (1943) and Laird (1954) (in both cases as *C. pseudomelanoconia* Theo.). Their descriptions are very brief and, since they differ from one another in certain respects, it has been thought desirable to redescribe and refigure the larva from material forming part of the type series. Details follow. *Head*: Antenna about two-thirds the length of the head, dark for its whole length, strongly spiculated basad of the antennal tuft, less strongly so beyond it, the tuft well developed with numerous delicate branches which are rather more than half the length of the antenna, subterminal setae arising shortly before the tip. Clypeal spines long, slender, simple, sharply pointed. Inner setae of mouth-brushes stout with numerous teeth. Head seta A (in the notation of Hopkins, 1952) with about 8–10 branches, B and C each with about 5–6, *d* and *e* single or bifid, *f* bifid. Mentum small with seven teeth on either side of the main central tooth, the basal tooth very small. Comb of 29–37 narrow, dark scales. First and third pentad setae strong, plumose, about 6–9 branched; second slender, bifid, arising from a large sclerotized plate; fourth long, slender, single; fifth strong, plumose, with about four branches. Pecten of 16–22 curved spines, those at the base small and atypical, the more typical distal ones with a distal fringe of fine denticles and 1–2 coarse denticles at the base. Siphon tapering sharply on the basal half, more gradually on the distal



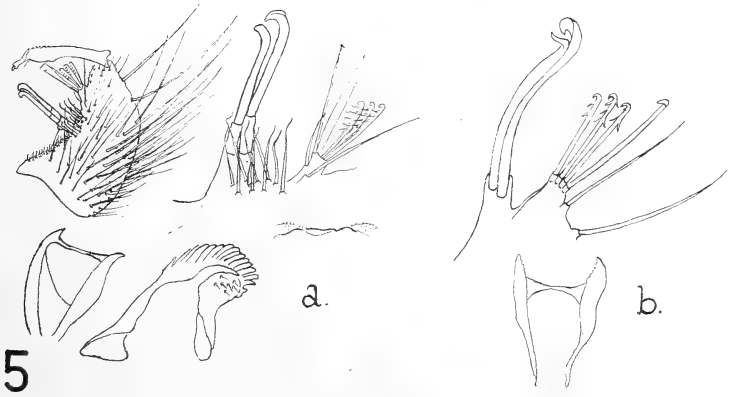


Fig. 4.—*Culex cheesmanae*, n. sp. Early stages. *a*. Pupal trumpet. *b*. Head and terminal segments of 4th instar larva.

Fig. 5.—Male terminalia. *a*. *Culex cheesmanae*, n. sp. Coxite and style, subapical lobe of coxite, phallosome, paraproct and Xth tergite, IXth tergite. *b*, *Culex pseudomelanoconia* Theo. Subapical lobe of coxite, phallosome (specimen from Burpengary, Qld.).

Fig. 6.—*Culex tricuspis* Edwards. Terminalia of holotype male. *a*. Coxite and style. *b*. Paraproct and Xth tergite. *c*. Phallosome.

half. Index about 7·5. In some cases a rather nebulous dark band is apparent on about the middle quarter. Subventral setae of siphon arising near the midline, each about six times the diameter of the siphon at point of attachment and with 4–6 branches. Dorsal to this submedian row are 3–4 delicate single or, occasionally, bifid setae on either side, the most distal of which lies beyond the end of the sub-median row about half-way between this and the apex of the siphon. The spines on the dorsal valves of the siphon are long, slender and curved. Saddle complete, its distal edge spiculate but only slightly more so than the adjacent parts of the general surface. Saddle hair bifid to tetrafid, about twice as long as the saddle. Upper caudal seta with 5–6 branches, lower single. Setae of ventral brush with numerous branches, two precratal tufts present. Dorsal pair of anal papillae narrow, pointed, about half as long again as the saddle. Ventral pair somewhat shorter than the dorsal.

Variation. Miss Cheesman's larvae and adults are both decidedly paler than those from Nassirah. The effect may have been enhanced by ageing but appears to be to a large extent intrinsic. It may be an altitudinal effect or it may be associated with individual differences in breeding waters. The similarity in dates of collection suggests that it is not a seasonal effect.

Synonymy. The larva figured by Laird (1954) is stated to have head seta B double, C single and *d* branched (figured as double). There can be no doubt that this is an error arising from the fact that ventral setae have been mistaken for dorsal. Working with skins this would be an easy mistake to make, particularly as the multiple branching of setae B and C in the present species is most unusual in *Neoculex* (see below). There appears to be no other reason to doubt that both Laird and Williams described the larva of the present species.

Relationships. Edwards (1932) divided the subgenus *Neoculex* into three groups. The same author later (1941) added two further groups, one of these being formed by separating eight species which had previously been grouped under the name *Culex rima* Theobald. King and Hoogstraal (1947) proposed the creation of a sixth group to contain a new species described by them from New Guinea together with *Culex crassistylus* Brug. These groups have no practical value and since they are based on an arbitrary choice of characters, other characters which may well have equal significance being ignored, they can give little idea of relationships. The comments which follow are offered mainly as an illustration of the difficulties involved in determining relationships in this group and of the desirability of exercising caution until all the known members have been adequately described. The outstanding characters of the present species appear to be the pilose mesepimeron, the hairy abdomen, the structure of the female pharynx, the ornamentation of the subapical lobe of the male coxite, the smooth phallosome, absence of fine setulae from the crest of the paraproct, reduction of the male and female ninth tergite, structure of the larval mouth brush, multiple branching of larval head setae B and C, structure of the pecten teeth and long subventral tufts of the siphon. One of us (P.F.M.) is engaged on a comprehensive study of this subgenus and it is hoped that in due time it will be possible to study all these characters on a comparative basis. The present comments are in the nature of an interim statement based on the limited information at present available.

Mesepimeron. The pilose condition is very unusual. A similar condition is, however, shown by a West African member of the *Culex rima* group, *Culex calabarensis* Edwards. The latter has a well-developed lower mesepimeral bristle in both sexes. The present species has not.

Female pharynx. The pharyngeal armature of the present species is unlike that of *C. calabarensis* but closely resembles that of another member of the *C. rima* group occurring in the West African subregion, *Culex andreanus* Edwards. The pharynx of *C. calabarensis* resembles that of yet other members of this group. Only the pharynxes of the Ethiopian and one Oriental member of the subgenus have previously been described (see Edwards, 1941; Barraud, 1934).

Abdomen. The very hairy abdomen recalls the Mediterranean *Culex impudicus* Ficalbi, in which, however, it mainly characterizes the male.

Male terminalia. It is not proposed to discuss the ornamentation of the subapical lobe of the coxite in detail. This is because even the best of the many published descriptions of this structure are insufficiently critical while some of the worst are grossly misleading, as, e.g., the description and figure of *Culex salisburiensis* Theobald by Edwards (1941) (see Knight, 1953). It is clear that in all or nearly all the members of the subgenus the seemingly very various types of ornamentation are derived from a single basic setal pattern and there is good reason to believe that a careful study of the extensive material available will furnish first-rate evidence regarding relationships. The smooth phallosome is characteristic of a number of Mediterranean species, though not of the holarctic *Culex territans* Walker and its allies or of *C. impudicus*. Some species are intermediate, as, e.g., the Australian *Culex pseudomelanoconia* Theobald (Fig. 5*b*) and the very interesting *Culex deserticola* Kirkpatrick, which has a close ally, *C. salisburiensis* occurring along the line of the East African highlands from Abyssinia to the Cape of Good Hope (Mattingly, 1954). The crest of the paraproct shows reduction of the finer setae in most of the Mediterranean *Neoculex* (including a new one from Baluchistan, of which a description is in the press) and in *C. salisburiensis*. It would seem that in most of the Ethiopian species these setae are more strongly developed, and the same is true, curiously, of the Mediterranean *Culex hortensis* Ficalbi, which has a smooth phallosome. The latter species is the only one at present known to us which resembles *C. cheesmanae* in the extreme reduction of the ninth tergite. The reduction of the ninth tergite of the female is probably equally significant, but, so far as we are aware, the present species is the only *Neoculex* for which the female terminalia have been described.

Mouth-brushes and larval head setae. The presence of stout, toothed setae in the mouth-brushes is characteristic of many species breeding in tree-holes, leaf axils and containers of various kinds. It is, however, extremely rare in the subgenus *Neoculex*. Even the larvae of the Ethiopian tree-hole breeding species *Culex albiventris* Edwards, *Culex adersianus* Edwards, *Culex acrostichalis* Edwards, *Culex wansoni* Wolfs and *Culex horridus* Edwards do not show them. They are, however, exhibited by the very remarkable larva of *Culex stellatus* Van Someren from the Seychelles, the zoogeography and relationships of which have been discussed by Mattingly and Brown (1955). The same is true of the multiple head setae. Toothed mouth-brush setae are also shown by the highly specialized larva of *C.* (*Neoculex*) *sumatranus* Brug, but, like other pitcher plant breeders, this has greatly reduced head setae.

Siphon and pecten. These recall the subgenus *Lophoceraomyia* (for which see Mattingly, 1949) and may, perhaps, be mentioned as illustrating the close relationship which undoubtedly exists between this and *Neoculex*. There is also a striking resemblance between the pecten and siphon of *Culex prosecutor* Séguy (1927, figured by Séguy, 1925, as *Culex pseudomimeticus* Séguy, *nec* Sergent). This is a highly interesting species from the south of France which is still known only from the larva. Edwards (1932) treated it as a species *incertae sedis* but it seems very likely that it is a *Neoculex*.

Distribution. Since this species is confined, so far as is known, to New Caledonia, little can be said regarding its geography beyond noting the markedly different altitudes at which the two sets of specimens available to us were collected. Before discussing the distribution of its close relatives it is necessary to determine which these are and, as has been seen, this is not very easy. The most that can be said at present is that *C. cheesmanae* appears to possess characters relating it both to the Mediterranean (and East and South African) species group and to the West African species group. It might be inferred from this that it is a primitive annectent species. This is a rather facile assumption, but it seems to receive some support from the characters of the larval head. Thus the multiple head setae undoubtedly suggest some affinity with species of subgenera other than *Neoculex* while the remarkable mouth-brushes suggest even remoter affinities. It must, however, be stressed that in assessing the value of larval characters such as these it is necessary to allow for coenogenesis and kindred phenomena (see, e.g., De Beer, 1951, on *Culex moucheti* Evans).

CULEX (NEOCULEX) TRICUSPIS Edwards.

Culex trifidus Edwards, *Bull. ent. Res.*, 17: 108, 1926. *Culex tricuspis* Edwards (nom. nov.), *ibid.*, 21: 294, 1930. *Culex* (*Neoculex*) *tricuspis* Edwards, *Genera Insect.*, 194: 194, 1932.

This species is annectent between the subgenera *Culiciomyia* and *Neoculex*. On the basis of the head scaling it would be placed in the former, but the absence of modified scales from the male palps and the presence of apical pale bands on the abdominal tergites appear to justify its inclusion by Edwards in *Neoculex*. The male terminalia are perhaps the most remarkable in the whole genus. They were well described by Edwards (1926) but have not been figured. It has therefore been thought worth while to include a figure in the present paper (Fig. 6). The species is at present known only from the unique holotype male from Alor I. in the British Museum (coll. Rodenwaldt, —:i:1926). The trifid style is unique and can be compared only with the bifid style of the Indomalayan *C.* (*Culiciomyia*) *spathifurca* Edwards (figured by Carter and Wijesundara, 1948, as *C. stylifurcatus*, n. sp.). The basic structure of the style is, however, closer to that of many species of the subgenera *Culiciomyia*, *Lophoceraomyia* and *Mochthogenes* and a few remarkable species of the typical subgenus, e.g. the Polynesian *C. atriceps* Edwards and the Ethiopian *C. nakuruensis* Mattingly. The remarkable outgrowth from the subapical lobe of the coxite with its crown like that of the paraproct can only be compared with that found in the Mediterranean *C.* (*Neoculex*) *hortensis* Ficalbi, but here the crown is replaced by a flattened, vesicular structure. The phallosome recalls that of the Ethiopian *C.* (*Culiciomyia*) *subaequalis* Edwards which it very closely resembles. The pilose Xth tergite recalls *C.* (*Neoculex*) *peringueyi* Edwards from the Cape Town area of South Africa. The membranous IXth tergite recalls *C. cheesmanae* and *C. hortensis*.

CULEX (NEOCULEX) CHAETOVENTRALIS (Theobald).

Neomelanoconion chaetoventralis Theobald, *Mon. Cul.*, 5: 461, 1910. *Culex* (*Lophoceratomyia*?) *chaetoventralis* Edwards, *Bull. ent. Res.*, 14: 397, 1924.

The type female is in the British Museum (Natural History) collection. The discovery of males and larvae enables this species to be placed with certainty in the subgenus *Neoculex*. Theobald gave the type locality as "Kumanda", and this is also on the locality label of the type, but is obviously a mis-spelling of Kuranda; Edwards (1924) gives the correct spelling.

Adult ♀. Two additional ♀♀ agree well with Theobald's description and with the type specimen. The thoracic integument is brown; the scutum has a narrow anterior and lateral border of lighter grey, parallel to which on the pleuron there is a broad grey band across the lower half of the posterior pronotum, subspiracular area, upper sternopleuron and middle of the mesepimeron; below this again the coxae are pale. Anterior pronotum bare of scales. Posterior pronotum bare of scales or with 2–3 narrow curved scales on its upper border; 3–5 bristles. Scutal scaling bronzy rather than golden brown, with paler scales on the pale border; acrostichal and dorsocentral bristles very strongly developed. Scutellum with six bristles to the mid-lobe and four to the lateral lobes. A patch of broad pale scales on the upper sternopleuron overlying the pale integument; a few pale scales also along the lower posterior border in front of the bristles. Mesepimeron devoid of scales; about 10 pale upper and no lower mesepimeral bristles. Wings dark, length 2·6–2·9 mm. A short streak of pale scales at the base of R_1 (the type has quite a long stripe of pale scales covering R and part of the proximal portion of R_1; this is not mentioned in the original description). Upper fork cell 1·7–2·0 times the length of its stem, lower 0·7 times its stem. Knob of halteres dark scaled above, pale beneath. *Legs*: Coxae pale scaled, fore femur equal in length to proboscis; hind femur with pale anterior and posterior streaks, almost to apex. *Abdomen*: Second tergite with large sublateral basal pale patches joined medially by a narrow band; third to sixth with almost complete basal bands widest laterally and interrupted by dark scales medially; sternites pale scaled with apparently some darker, reflecting scales laterally and apically. The tip of the abdomen is not down curved in these specimens.

Adult ♂. Differs from the ♀ as follows: Palps straight, black scaled, 1·3 times the length of the proboscis (the tip of which, excluding the labella, reaches the middle of the fourth palpal segment); a few long dark hairs at the apices of third and fifth segments, long and short hairs along the fourth and fifth segments. Scutellum with 5–6 bristles to mid-lobe, 3–4 to lateral lobes. Wing length 2·5–2·9 mm.; upper fork cell 1·5 times the length of its stem. Anterior claw of fore- and mid-legs long with a sharp, strongly developed tooth, posterior claw smaller, simple; hind claws small, equal,

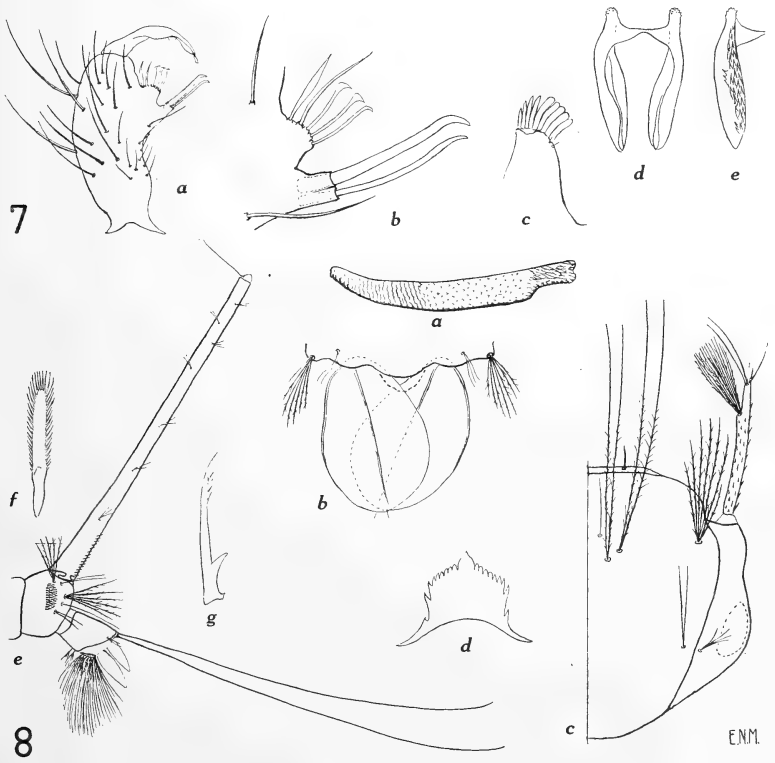


Fig. 7.—*Culex chaetoventralis* (Theobald). Male terminalia. *a*. Coxite and style. *b*. Subapical lobe of coxite. *c*. Paraproct and Xth tergite. *d*. Phallosome, tergal view. *e*. Lateral plate of phallosome, sternal view.

Fig. 8.—*Culex chaetoventralis* (Theobald). Early stages. *a-b*. Pupa. *a*. Trumpet. *b*. Paddles. *c-g*. 4th instar larva. *c*. Head. *d*. Mentum *e*. Terminal segments. *f*. Comb scale. *g*. Pecten spine.

simple. Second tergite with large lateral basal pale patches, reaching almost to the apex, and joined by a narrow band medially, or entirely pale scaled, except for a medial apical dark patch, third to seventh tergites with fairly straight broad basal bands, which may be narrower medially on the seventh; eighth white-scaled laterally, dark medially. Numerous hairs on the sternites and laterally on the tergites, a few also along the apical borders of the tergites. *Terminalia* (Fig. 7): Style stout, curved, narrowing near the tip, without preapical crest; 2–3 setulae arising on the distal half.

Terminal appendage short, with expanded, rounded tip. The two portions of the subapical lobe of the coxite not widely separated; the distal portion bears a row of five setae, three moderately stout, with slightly recurved, flattened tips, one longer unmodified seta, and one slender leaflet and, in addition, a strong detached seta arises near their base; the proximal portion bears two ligulate setae with slightly curved tips, the distal one being the stouter; a long strong seta arises near their base. Lateral plates of phallosome joined by a narrow sclerotized bridge fairly close to their tips, which are rounded and bear minute denticles; on the sternal aspect, the inner surface of the lateral plates is covered with flat, appressed spines, their points directed distally. Paraprocts with nine relatively broad blunt teeth and without sub-basal arm; Xth tergites lightly sclerotized with 2–3 microsetae near the point of attachment. Lobes of IXth tergite distinct, with 3-4 setae.

Pupa (Fig. 8, *a*, *b*). The longer setae are usually lightly plumose. *Cephalothorax*: Trumpet long, slender; meatus four-fifths of greatest length. Seta 1 long, stout, bifid or trifid; 2 long, slender, bifid or trifid; 3 long, stout, single; 4 short, slender, bifid or trifid; 5 long, moderately stout, bifid to tetrafid; 6 short, slender; 7 moderately long, slender, both trifid or tetrafid; 8 long, stout, bifid to tetrafid; 9 moderately long, slender, bifid. *Metanotum*: Setae 10 and 12 moderately long, slender, bifid or trifid; 11 short, single or bifid. *Abdomen*: Segment I with seta 1 dendroid, strongly developed, with 9–11 primary branches which are further subdivided; 2 short, single; 3 long, stout, single; 4 short, bifid to tetrafid; 5 short, tetrafid to hexafid; 6 long, stout, single; 7 short, single; 10 moderately long, slender, single to trifid. Segment II with seta 1 short, fine, with 6–10 branches; 2 small, single; 3 moderately long, single; 4 short, trifid to heptafid; 5 moderately long, slender, bifid to tetrafid; 6 long, stout, single; 7 minute, single; 10 moderately long, slender, bifid. Segment III with seta 1 moderately long and stout, with 8–13 branches; 2 minute, single; 3 moderately long, stout, single; 4 short, trifid to hexafid; 5 and 6 moderately long, slender, 5 trifid to tetrafid, 6 bifid or trifid; 7 minute, single; 8 short, tetrafid to heptafid; 10 short, trifid to heptafid; 11 short, single; 12 moderately long, slender, bifid. Segment IV with seta 1 long, stout, bifid to tetrafid; 2 minute, single; 3 short, with 7–11 branches; 4 short, bifid or trifid; 5 long, stout, trifid or tetrafid; 6 moderately long, slender, single or bifid; 7 minute, single; 8 short, trifid or tetrafid; 10 short, bifid to tetrafid; 11 short, single; 12 moderately long, slender, single or bifid. Segment V with seta 1 moderately long, slender, single or bifid; 2 minute, single; 3 short, bifid or trifid; 4 short, with 6–8 branches; 5 long, stout, bifid; 6 moderately long, slender, single or bifid; 7 minute, single; 8 short, bifid to tetrafid; 10 short, with 6–9 branches; 11 short, single; 12 moderately long, slender, single. Segment VI with seta 1 moderately long, slender, single or bifid; 2 minute, single; 3 short, bifid or trifid; 4 short, bifid to pentafid; 5 moderately long and stout, single or bifid; 6 moderately long, slender, single or bifid; 7 minute, single; 8 short, trifid to pentafid; 10 and 12 moderately long, slender, single; 11 short, single. Segment VII with seta 1 moderately long, slender, bifid; 2 minute, single; 3 short, trifid to pentafid; 4 short, bifid or trifid; 5 moderately long, slender, single; 6 short, trifid to hexafid; 7 long, very stout, plumose, with 4–8 branches; 8 short, trifid to hexafid; 10 moderately long, slender, single; 11 short, single; 12 moderately long, slender, single or bifid. Segment VIII with seta 5 moderately long, slender, bifid or trifid; seta 7 long, very stout, plumose, with 5–8 branches. Paddles oval, index 1·3–1·5, with well-developed buttress and midrib and inconspicuous small spines scattered along the margin; seta 1 single or bifid. Dorsal sensillum present near seta 4 on segments III–V. Seta 0 present on segments II–VIII, and 14 on segments III–VIII.

Larva (Fig. 8, *c-g*). *Head* slightly broader than long, rounded posteriorly. Antenna about one-half the length of the head, concolorous brown, strongly spiculated basad of the antennal tuft which arises at three-quarters length; tuft well developed with numerous branches, which are rather more than half the length of the antenna, subterminal setae arising shortly before the tip. Clypeal spines fairly short, slender, simple, sharply pointed. Setae of mouth-brushes simple. Head seta A 7–9 branched, B and C bifid, *d* single (occasionally with short bifurcation), *e* bifid or trifid, *f* trifid

to heptafid. Mentum small, with 8–9 teeth on either side of the large pointed central tooth, the basal tooth small. Comb of 50–60 slender, fringed scales; first pentad seta strong, plumose, 4–6 branched; second slender, simple, bifid or trifid; third strong, plumose, 6–9 branched; fourth simple, single; fifth stout, lightly plumose, single or bifid. Pecten of 11–18 spines, those at the base small and atypical, the more typical distal ones with a very strong pointed sub-basal tooth, sometimes a small basal tooth also, and with a distal fringe of 2–4 fine denticles. Siphon tapering sharply near base, then more gradually, index 9·0–12·0; five pairs of fine 2–5 branched subventral setae, each about equal to the diameter of the siphon at point of attachment, the more basal setae arising laterally; arising dorsal to the two distal pairs are two pairs of single to tetrafid setae. Dorsal valves of the siphon each with a long slender seta, about three times the diameter of the tip of the siphon. Saddle complete, its distal edge spiculate, but only slightly more so than the adjacent parts of the general surface. Saddle hair bifid to tetrafid, one half as long as the saddle. Upper and lower caudal setae single. Ventral brush of 14 setae, the distal ones with 9–12 branches; 2–4 of these tufts are precratal. Anal papillae stout, bluntly pointed, the upper pair four-fifths as long as the lower pair, which are equal in length to the saddle.

Relationships. Though the adults are abundantly distinct, the larva of *C. chaetoventralis* bears a close resemblance to that of *Culex* (*Neoculex*) *brevipalpis* (Giles) but can be distinguished by the shape of the pecten spine (which in *C. brevipalpis* has a fringe of fine denticles but no large sub-basal tooth), the long seta of the dorsal valve, and the presence of precratal tufts. In the long palps, the basally banded abdomen and the structure of the paraproct, the male of *C. chaetoventralis* resembles the New Guinea species *Culex* (*Neoculex*) *crassistylus* Brug and *Culex* (*Neoculex*) *pedicellus* King and Hoogstraal but differs from them in the absence of flat scales bordering the eyes. It further resembles *C. pedicellus* in the presence of appressed spines on the lateral plate of the phallosome, but the two species differ markedly in characters of the coxite and style.

Distribution. Known only from north Queensland. The type locality is Kuranda, and the above descriptions are based on the following specimens in the University of Queensland collection: Two ♂♂ and one ♀ with correlated larval and pupal skins and two whole larvae from Kuranda (23:vi:1946), two pupae containing males ready to emerge, with correlated larval skins, and two whole larvae from Lake Barrine (9:vi:1946) and one ♀ with correlated larval and pupal skins from Berner Creek near Innisfail (13:v:1952), all collected by E. N. Marks.

Biology. C. chaetoventralis breeds in tree-holes in rain-forest. At Kuranda larvae were found in a cavity about 5 in. in diameter and 10 in. deep in the buttress of a rain-forest tree, and in a rot-hole about 4 in. in diameter and 18 in. deep in the trunk of a smaller tree. At Lake Barrine, the breeding place was a deep groove in a large fallen tree, holding a narrow pool of water about 8 ft. long and up to 1 ft. deep; 6–8 gallons were siphoned off without emptying it. At Berner Creek, *C. chaetoventralis* was breeding in a cup-like depression holding about 1½ pints of water, in a buttress of a tree-stump. In all cases the water was fresh and somewhat discoloured, and contained rotting leaves and debris. Associated larvae included *Aëdes notoscriptus* (Skuse), *Aëdes quasirubithorax* (Theobald), *Aëdes candidoscutellum* Marks and *Tripteroides quasiornata* (Taylor).

The pupal period occupied about four days but would probably be less in summer.

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THE DIPTERA OF KATOOMBA.

Part I.—Therevidae.

By G. H. Hardy.

(Four Text-figures.)

[Read 27th July, 1955.]

Synopsis.

A list of ten species previously recorded from the Blue Mountains of New South Wales is given, to which is added two species of *Anabarhynchus,* one new, the other previously recorded only from Tasmania. Notes are given bearing upon problems in the taxonomy of the family.

Introduction.

Since the revision of Australian Therevidae was made in Mann (1928–33), little attention has been given to the problems of taxonomy of this family (Hardy, 1939, and Paramonov, 1950), so the identity of some genera remains unknown or uncertain, and the limits and validity of others may be questioned. Those cases affecting the Therevidae of the Blue Mountains of New South Wales are two genera containing four species erected in Krober (1912), these being still unrecognized, namely, *Belonalys* and *Spatulipalpa.* The recorded species are as follows:

Evansomyia phyciformis White, 1915.
Anabarhynchus latifrons Macquart, 1849.
calceatus Schiner, 1868.
Acupalpa albitarsa Mann, 1929 (male only).
semirufa Mann, 1929.
Lonchorhynchus segnis White, 1915.
Belonalys obscura Krober, 1912 (male only).
gracilenta Krober, 1912 (female only).
Spatulipalpa paradoxa Krober, 1912 (male only).
ornata Krober, 1912 (male only).

On both Hobart and Katoomba specimens, *E. phyciformis*, normally only one pair of scutellar marginal bristles occurs, not four bristles as published. On Hobart specimens (3 ♂♂, 3 ♀♀, January, 1955) the eyes were red with, on the male, green from a little above the antennae extending downwards, and on the female a green bar at antennal level.

Genus Anabarhynchus Macquart.

In the *calceatus* group of this genus are four species, three of which are distinguishable mainly by coloration of the anterior femur.

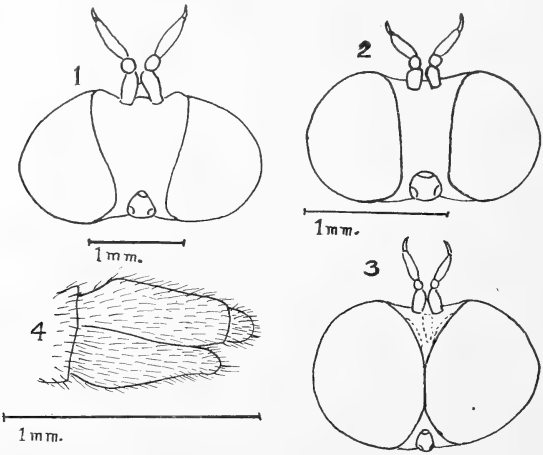
A. validus Mann (*calceatus* White, *nec* Schiner) has the eyes widely separated, being at the summit about twice the width of the ocellar tubercle. It is only known from Tasmania, occurring mainly in the spring.

A. calceatus Schiner and the two species given below have the eyes set much closer to the ocellar tubercle. The anterior femur is entirely black, or practically so, and the form occurs in the lowlands of the eastern States, apparently below 2000 feet elevation.

A. montanus White is found on the higher hills and mountains in Tasmania, and recorded below also from the Blue Mountains at above 3000 feet elevation. The anterior femur has the basal half, or a little more, black and the apical half brown.

A. kosciuskoensis Mann, so far only known from Mt. Kosciusko, has the anterior femur entirely brown.

It will be noted that three forms grade in colour of the anterior femur with altitude, and hence these three are, perhaps, subspecific in value. The single record of *A. calceatus* from Blackheath (3490 feet) needs confirmation, as an error may have been made. The other Blue Mountains locality, Woodford, is below 2000 feet.



Text-figures 1-4.—1. *Anabarhynchus montanus* White, head of female dorsal view. 2. *A manni*, n. sp., head of female, dorsal view. 3. The same of the male. 4. Hypopygium of the same, lateral view.

ANABARHYNCHUS MONTANUS White.

Chaetotaxy. Five specimens show a wide variation in bristles of the thorax and legs. The dorsocentrals are two in each row and placed in the prescutellar position. The notopleurals (prealar in Mann, 1928–33) are three to five, and when reduced to four either the foremost or the central one may be missing, but when only three remain, then the foremost and one of the others is missing. The supraalars are always two, and one postalar stands on the much-reduced postalar callus (the latter is included with supraalars in Mann, 1928–33).

Bristles of the femora vary, but normally four occur in a row placed on the posterior side of the first pair, but these vary from five to three, whilst occasional bristles may occur elsewhere, including ventral ones. The second pair may have two or one subapical bristles similarly placed, but this may increase to four, and similarly occasional bristles may be present, especially a ventral row. The hind femora never seem to vary from having one or two subapical bristles on the anterior side, but some occasional bristles may occur.

Habitat. New South Wales: Katoomba, five females, November to December, 1952–5, to which the above note on chaetotaxy applies. Tasmania: Mt. Wellington, three males, three females on 8th and 12th January, 1955, used for comparison and found to be more consistent in chaetotaxy, and darker in colour. These specimens were captured between 2000 and 3000 feet.

ANABARHYNCHUS MANNI, n. sp.

Male. Eyes, in life, red with green reflections, contiguous and, above antennal level, the facets are larger and with a distinct differentiating line. The frons is bright brown, very small below the ocellar triangle, and broadly triangular at the antennae, which part is as long as the line where the eyes meet, and there are no hairs. Antennae short

and brown, with the style black. Face grey, proboscis and palpi brown, both smaller than those of the female. Occiput grey, with a row of small black bristles above, these merging into two or three similar rows below.

Thorax bright brown; when in good order no markings are apparent. Three notopleural, one supraalar, one postalar, three to five postsutural dorsocentral and one pair of scutellar bristles are consistently present on all specimens. Pleural and postscutellar areas are grey, which colour tends to spread over the brown of the scutellum and near by, as a tinge.

Abdomen black above, grey ventrally, with white hairs and the apical margins of the segments are yellowish varying to white. Terminalia brown, with a little fuscous covering it wholly or in part.

The legs have dark grey coxae, the rest being brown with the apex of the tarsi a little darker. A trend towards darkening of the brown, in places, is noticeable on some specimens of the series. The femora have only one bristle situated on the third femur, subapically placed on the anterior side.

Female. Similar to the male, but the eyes are separated at the summit by nearly twice the width of the ocellar triangle, and some dark reflections may occur on the frons due to depressions. These are, normally, a dark median spot and a bar above it. Black hairs are scattered over the area. Two rows of bristles occur behind the eyes, merging into three rows below.

Thorax with a varying length of a thin dark median line, otherwise this and the abdomen conform with those of the male.

Habitat. Katoomba, three males, twenty-one females, from the end of November (26th) through December (28th is the last date), 1952–4. These were found on windows and when sweeping along a storm-water drain, but a few were haunting bare (cultivated) ground, behaving there very much as other species of the genus behave over more or less bare ground.

Note.—As far as is known, this species is the only one of the genus that has contiguous eyes on the male. The specific name given is in tribute to and appreciation of the papers on Therevidae by J. S. Mann.

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NEW SPECIES OF STAPHYLINIDAE FROM AUSTRALIA.

By W. O. Steel, F.R.E.S.

(*Communicated by J. W. T. Armstrong.*)

(Twelve Text-figures.)

[Read 27th July, 1955.]

Synopsis.

Four new species are described: *Megalopinus acaciae* (Steninae), *Paederus armstrongi*. *Dibelonetes rufoniger*, and *Stilicoderus aberrans* (Paederinae).

Thanks are due to Mr. J. W. T. Armstrong, Nyngan, N.S.W., and Mr. C. E. Chadwick, N.S.W. Department of Agriculture, for the opportunity of examining the insects described below.

Family STENINAE.

Megalopinus acaciae, n. sp.

Shining. Head and pronotum very dark brown, elytra dark brown, each with two yellow marks, one elongate, extending along the median part of the suture, the other transverse, behind the middle, extending from the external margin on to the disc, abdomen dark brown in front, becoming lighter apically. Antennae, palpi and legs yellowish-brown. Length: 2·6–2·7 mm.

Head across eyes a little wider than the pronotum, not as broad as the elytra, lateral angles of clypeus only slightly produced; clypeus depressed, impunctate, elsewhere very strongly, coarsely and closely punctured, the punctures tending to become confluent anteriorly. Antennae short, the first segment short and stout, almost hidden by the antennal tubercles, the second stout, not much shorter than the third, the third elongate, narrower than the second, the fourth quadrate, much shorter than the third, the fifth to seventh about as long as broad, the eighth very slightly transverse, the fourth to eighth about equal in breadth, the ninth a little wider, strongly transverse, the tenth strongly transverse, much longer and wider than the ninth, the eleventh large, as broad as the tenth, rounded apically.

Pronotum about one and one-sixth times as broad as long, broadest in front of middle, each side (seen from above) with three small teeth, one at the anterior angles, one a little behind this and one behind middle; surface irregular due to the very strong, coarse and close punctures which are confluent in places. Scutellum with an elongate fovea on each side extending to apex, the foveae separated by a narrow keel.

Elytra transverse, distinctly broader than the pronotum, the sutural length scarcely longer than the pronotum, widest behind the middle, the sides slightly rounded, the humeri well marked, the posterior angles hardly rounded, the posterior margin almost straight, the sutural striae well marked; each with an elongate impression at about the middle in which are some three or four indistinct, rather coarse punctures, external to this with a row of some five similar but well marked punctures which tend to form an elongate impression, surface otherwise smooth.

Tergites of abdomen smooth, without visible puncturation, those of the third to seventh (first to fifth visible) segments with eight small longitudinal keels basally.*

Tarsi simple, distinctly five-segmented, the posterior nearly three-quarters as long as the tibiae.

♂.—Posterior margin of tergite of the eighth segment lightly emarginate.

♀.—Posterior margin of tergite of the eighth segment rounded.

New South Wales: Acacia Plateau, 2 ex. (J. W. T. Armstrong).

* In some lights these keels appear as four small foveae, which would appear to indicate that the alternate spaces between them are somewhat depressed.

Holotype (♂) in the collection of J. W. T. Armstrong, allotype (♀) in the collection of the author.

This species is quite distinct from the other Australian species of the genus, *nodipennis* (Macl.), *denticollis* (Fvl.) and *melbournensis* (Wilson) by reason of its sculpture and the markedly smaller size.

From the material in the British Museum collection it seems that *M. denticollis* (Fvl.) and *M. nodipennis* (Macl.) are conspecific. An examination of Macleay's type would finally settle the matter.

Family PAEDERINAE.

Paederus armstrongi, n. sp. (Text-figs. 1 to 3.)

Shining. Head black, pronotum red, elytra blue-black, abdomen black, the eighth segment with at least the basal half red, sometimes wholly red, terminal segment red. Antennae with the first to tenth segments black, sometimes obscurely reddish at base, the eleventh light yellowish-red. Mandibles dark reddish-brown, maxillary palpi with the first to third segments black, the fourth reddish. Femora and tibiae black, tarsi reddish-brown. Length: *ca.* 11 mm. (with abdomen normally extended).

Head about as long as broad, the post-ocular region about twice as long as the eyes (seen from above), the sides rounded from the posterior margin of the eye to the neck. Surface finely and rather diffusely punctured, the punctures setiferous and somewhat unequal in size. Antennae long and slender, reaching (if extended backwards) to the base of the pronotum, the third segment about twice as long as the second, the fourth to tenth gradually decreasing in length but scarcely increasing in breadth, the fourth about twice as long as broad, the tenth about one and one-quarter times as long as broad, the eleventh nearly twice as long as the tenth, bluntly pointed apically.

Pronotum strongly convex, distinctly broader than head, very slightly longer than broad, broadest at about middle, the sides strongly rounded, the anterior and posterior angles completely rounded. Surface with punctures similar to those on head.

Elytra very short, about one and one-fifth times as broad as long, about as broad as pronotum, the sutural length about two-thirds as long as pronotum, distinctly widened behind, the sides almost straight, the humeral angles rounded. Surface with setiferous punctures which are about as close as those on head and pronotum but distinctly coarser.

Tergites of abdomen with setiferous punctures similar to those on pronotum.

♂.—Apical margin of sternite of the fourth segment slightly emarginate in middle, with a small, indistinct, tubercle on each side of the emargination and a superficial semicircular impression behind it, apical margin of sternite of fifth segment emarginate in middle, the right-hand side of the emargination produced into a more or less straight, apically truncate process which is directed obliquely inwards, the left-hand side produced into a straight pointed tooth with a small tubercle at base internally, behind the emargination with a distinct semicircular impression (Text-fig. 2). Sternite of the eighth segment with a deep, narrow, parallel-sided, median excision, the edges of which are bordered. Aedeagus with the median lobe asymmetrical, as in Text-figure 3.

New South Wales: Mount Irvine, 2 ex., including holotype (J. W. T. Armstrong), Megalong, 3 ex. (J. W. T. Armstrong), Mount Wilson, 1 ex. (Olliff).

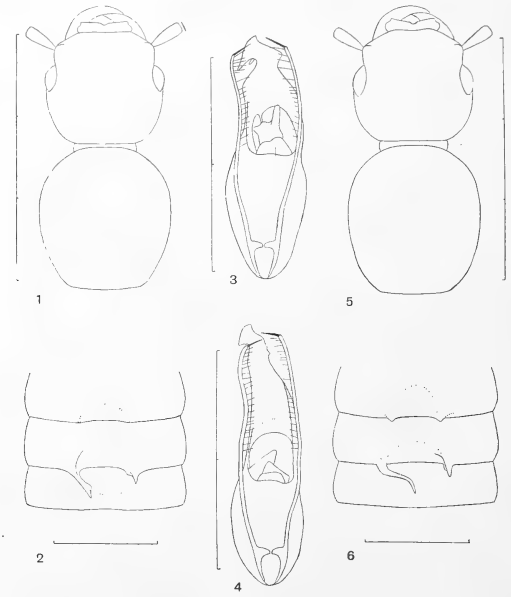
Holotype (♂), allotype (♀), and one paratype in the collection of J. W. T. Armstrong, two paratypes in the collection of the author, one paratype in the collection of the N.S.W. Department of Agriculture.

Paederus armstrongi is very similar to *P. sparsus* Fvl. (Text-figs. 4 to 6), but differs in the smaller eyes, the shorter, more rounded pronotum, the slightly closer puncturation on all parts and the red apex of the abdomen, as well as in the male secondary sexual characters and the aedeagus. As *P. sparsus* was described from a unique female and neither the male secondary characters nor the aedeagus have since been described, descriptions and figures of these are given here.

The sternites of the fourth and fifth abdominal segments show similar modifications to those of *armstrongi*, but, on the fourth, the lateral tubercles are more distinct and

the impression is half oval and, on the fifth, the right-hand side of the emargination is produced into a sinuate, apically pointed, inwardly directed process, the left-hand side is similar to *armstrongi*. The sternite of the eighth segment is identical with that of *armstrongi*, and the aedeagus, which also has the median lobe asymmetrical, is as in Text-figure 4.

P. armstrongi and *P. sparsus* are the only species of *Paederus* known to me which show such modifications of the sternites of the fourth and fifth abdominal segments. The modification of the sternite of the eighth segment is normal and is practically constant throughout the genus.



Text-figures 1-6.

1. *Paederus armstrongi*, n. sp., head and pronotum (scale = 3 mm.). 2. *P. armstrongi*, n. sp., sternites of 4th-6th abdominal segments (scale = 1 mm.). 3. *P. armstrongi*, n. sp., aedeagus (scale = 2 mm.). 4. *P. sparsus* Fvl., head and pronotum (scale = 3 mm.). 5. *P. sparsus* Fvl., sternites of 4th-6th abdominal segments (scale = 1 mm.). 6. *P. sparsus* Fvl., aedeagus (scale = 2 mm.).

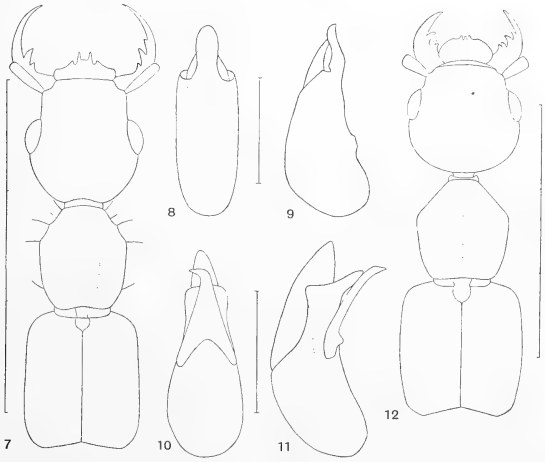
DIBELONETES RUFONIGER, n. sp. (Text-figs. 7-9.)

Rather dull. Head and abdomen black, pronotum red, elytra with the basal half black, the rest red, the two colours sharply differentiated. Antennae and mouthparts yellowish-red. Femora yellowish-red, darker apically, tibiae with about apical third yellowish-red, the rest darker, tarsi yellowish-red, the anterior legs (on the only specimen seen) have less darkening than the others. Length: 5·8 mm.

Head very slightly longer than broad, the eyes moderate and rather prominent, the ante-ocular region very slightly (about one and one-sixth times) longer than the eyes (as seen from above), with the sides almost straight, the post-ocular region a little less than one and one-half times as long as the eyes, distinctly broader immediately behind eyes than the ante-ocular portion, the sides rounded to the neck, the posterior angles obsolescent. Surface with close, rather large, irregularly shaped, umbilicate punctures, the intervals between the punctures forming a raised, irregular network,

with a few long setae towards sides. Antennae moderate, reaching (if extended backwards) a little beyond base of pronotum, the first segment as long as the next two together, the second short, longer than broad, the third distinctly longer, rather more than one and one-half times as long as the second, the fourth to tenth about equal in breadth, about as broad as the third, but decreasing gradually in length, the fourth only slightly shorter than the third, the tenth scarcely more than half as long as the third, all the segments longer than broad, the eleventh distinctly longer than the tenth, bluntly pointed apically.

Pronotum longer (about one and one-fifth times) than broad, broadest in front of middle, narrowed in font of widest point to neck with the sides slightly angulate, slightly narrowed behind, with the sides lightly rounded, the posterior angles rounded, the base shallowly emarginate, the sides somewhat impressed on basal half. Surface with punctures as on head. Scutellum alutaceous, indistinctly punctured.



Text-figures 7-12.

7. *Dibelonetes rufoniger*, n. sp., head and pronotum (scale = 3 mm.). 8. *D. rufoniger*, n. sp., aedeagus, ventral view. 9. *D. rufoniger*, n. sp., aedeagus, lateral view (scale for figs. 8 and 9 = 0·5 mm.). 10. *Stilicoderus aberrans*, n. sp., aedeagus, ventral view. 11. *S. aberrans*, n. sp., aedeagus, lateral view (scale for figs. 10 and 11 = 0·5 mm.). 12. *S. aberrans*, n. sp., head and pronotum (scale = 3 mm.).

Elytra distinctly (about one and one-fifth times) longer than broad, much broader (about one and one-third times) than the pronotum, the sutural length about as long as the pronotum, the sides more or less parallel, the humeral and posterior angles rounded, sutural angles obtuse so that the joint base is emarginate. Surface rather closely, indistinctly, granulate, each granule bearing a small setiferous puncture.

Tergites of abdomen finely, moderately closely, superficially punctured, the punctures setiferous. Surface distinctly alutaceous between the punctures.

♂.—Apical margin of sternite of the eighth segment emarginate in the middle, aedeagus as in Text-figures 8, 9.

New South Wales: Acacia Plateau, 1 male (J. W. T. Armstrong).

Type in the collection of J. W. T. Armstrong.

Four Australian species have previously been placed in the genus *Dibelonetes*—*antipodum* Bernh., *brevicollis* Lea, *mjoebergi* Bernh. and *palaeotropicus* Bernh. *D. rufoniger* is markedly different from these in the larger size and the coloration. The

only examples seen of any of the previously described Australian species—*D. palaeotropicus* Bernh., det. Bernhauer—do not agree at all well with *Dibelonetes* and are probably referable to *Sunesta* Blackwelder.

Besides the coloration, *D. rufoniger* differs from all other described species of the genus in the granulate sculpture of the elytra.

STILICODERUS ABERRANS, n. sp. (Text-figs. 10–12.)

Rather dull, the abdomen a little more shining. Body black, antennae, mouthparts and legs reddish-brown. Length: 7·25 mm.

Head about as broad as long, moderately convex, almost semicircular behind the eyes, the post-ocular region about one and two-third times as long as the eye (seen from above). Surface very finely and extremely closely punctured, the punctures to a large extent confluent, setiferous, the setae mostly very short but some longer, only the extreme apex of each antennal tubercle impunctate; on the sides, behind the eyes, the punctures are practically completely obscured by a fine, close, alutaceous ground sculpture, the whole of the undersurface of head with similar ground sculpture. Antennae not very long, reaching (if extended backwards) only to the middle of the pronotum, the first segment almost as long as the next two together, the second short, slightly longer than broad, the third longer, about one and one-third times as long as the second, the fourth to tenth decreasing gradually in length, the fourth a little shorter than the third, about one and two-third times as long as broad, the tenth very slightly transverse, the eleventh more than one and one-half times as long as the tenth, bluntly pointed apically, all the segments about equal in breadth.

Pronotum very slightly longer than broad, broadest in front of middle, strongly narrowed in front of the broadest part to neck with the sides almost straight, slightly narrowed behind the widest point with the sides lightly rounded, posterior angles rounded, base shallowly emarginate. Surface with punctures similar to those on head, on basal two-thirds with a very narrow, channelled, impunctate median line, superficially impressed on disc on each side of this line. Scutellum rounded behind, very finely and very closely alutaceous.

Elytra a little longer than broad, distinctly (about one and one-third times) broader than the pronotum, the sutural length about as long as the pronotum, broadest at about middle, the sides lightly rounded, the humeral angles rounded, the posterior angles rounded, the sutural angles obtuse so that the joint base is emarginate. Surface extremely closely, rugosely granulate, each granule bearing a small setiferous puncture.

Tergites of abdomen closely and extremely finely punctured and pubescent, the surface between the punctures with a close, fine, alutaceous ground sculpture.

♂.—Apical margins of the sternites of the seventh and eighth abdominal segments very shallowly emarginate over their whole length and fringed with close-set long setae. Aedeagus as in Text-figures 10, 11.

New South Wales: Acacia Plateau, 1 male (J. W. T. Armstrong).

Type in the collection of J. W. T. Armstrong.

Although this species agrees perfectly with *Stilicoderus* Sharp in the structure of the mouthparts, legs and thoracic sterna, it differs markedly from the other members of the genus in the sculpture and the length of the elytra. In these the pronotum is distinctly granulate, with the granulation extending on to the pronotum, and the elytra are markedly transverse, the sutural length much shorter than the pronotum, and the surface has a number of very large punctures arranged more or less in rows and between these fine setiferous granules. The humeral angles, although broadly rounded, are distinctly rectangular. In *S. aberrans* the pronotum is very closely punctured, without trace of granules, and the prosternum finely and closely alutaceous, the elytra are much longer and have no large punctures, but are closely, rugosely granulate. An undescribed species from New Guinea is in some ways intermediate between typical *Stilicoderus* spp. and the present species in that the elytra are somewhat longer, with the humeral angles obtuse, the elytral punctures rather less distinct with the granules

less fine and much more numerous; the pronotum (and prosternum) is, however, granulate.

Blackwelder (1939, *Proc. U.S. Nat. Mus.*, 87: 107) places *Stilicoderus* Sharp as a synonym of *Stiliderus* Mots. (= *Psilotrachelus* Kraatz). Whilst there is no doubt that the two genera are very similar in general facies, there are so many small points of difference that *Stilicoderus* must be given at least subgeneric rank. In *Stiliderus* the labrum is differently formed, the sides of the head are strongly bordered below and the fourth tarsal segment is strongly bilobed.

THE OCCURRENCE OF THREE NEW WHEAT STEM RUSTS IN AUSTRALIA.

By I. A. Watson, Faculty of Agriculture, University of Sydney.

[Read 27th July, 1955.]

Synopsis.

The reactions of three new stem rusts of wheat are recorded. Each would be described as a different race on the accepted group of differential varieties. The first is race 21, which has been listed as race 21 Anz 1 to denote its presence in the Australia-New Zealand geographical area. It is characterized by the ability to attack seedlings and adult plants of Celebration. The significance of the other two, race 126 Anz 3 and race 222 Anz 4, has yet to be established.

Introduction.

Breeding for stem and leaf rust resistance is being carried out in the major wheat-producing countries of the world. It is recognized that for this work to be successful concomitant studies dealing with the variability of the two organisms *Puccinia graminis tritici* and *Puccinia triticina* must be undertaken. Results from different countries have clearly established the fact that new rusts occur from time to time and detection of them is facilitated by the screening action resulting from the commercial cultivation of varieties that serve as differentials.

Results of Breeding Rust-Resistant Wheats.

In Australia the occurrence of new races of rust following the release of resistant varieties has been reported in a number of cases (Watson and Waterhouse, 1949; Waterhouse, 1952; Watson and Singh, 1952). New types of *P. triticina* and *P. graminis tritici* have appeared. Gabo, initially resistant to rusts of both groups, became widely cultivated in 1944, and in 1945 leaf rust was found on it for the first time at Wee Waa, N.S.W. At present, Gabo is one of the most leaf rust susceptible varieties and it has been shown that a whole series of races are involved (Waterhouse, 1952; Watson, unpublished). In breeding work considerable use has been made of Hope resistance to leaf rust, and at Castle Hill, N.S.W., the derivatives Hofed (Federation × Hope) and Warigo (Hope × Nabawa) are extensively grown. In 1951 for the first time leaf rust was found on both varieties, but it appeared confined to this one area. During 1954–55, however, both varieties were rusted by *P. triticina* at widely scattered places in New South Wales. Here also no single race is responsible and, using seedlings of Renown, several rusts to which the latter is susceptible can be separated. These, on the basis of overseas work, are assumed to be virulent on adult plants of Hope derivatives. Spica (Kamburico × Three Seas) can also be mentioned with the other leaf rust material. This variety, while susceptible now, was initially resistant in Queensland, where it was developed (personal communication from Dr. L. G. Miles), but it has always been rusted in the field by *P. triticina* in New South Wales according to our observations since 1950. This can be explained by results which show that among the Australian leaf rusts are some that attack Spica while others do not. At present no commercial variety in eastern Australia is resistant to all races of leaf rust. Several resgenes have been identified, however, which are highly effective against the known pathgenes. The breeding procedure is well defined and is being carried out according to a predetermined scheme.

The evolutionary changes have been similar in the organism causing wheat stem rust. Eureka was made available in the late thirties, and in 1942 from Narrabri a stem rust designated 126B was found on it. Charter, Gabo, Yalta and Kendee increased rapidly in popularity in the mid-forties, but in 1948 they, too, fell to new rusts (Waterhouse, 1952). It was predicted that they would become susceptible simultaneously on account of their genetic relationship (Watson and Waterhouse, 1949). The complete

details of all the stem rusts commonly occurring in Australia are given herein. Those of other rusts have already appeared (Waterhouse, 1952). In a study of these common rusts much attention has been given to the commercial varieties that have retained their resistance in spite of the major changes in the dominant rust flora. Until the 1954–55 season those considered to be resistant to all stem rusts in the field were: Celebration (Marquillo), Spica (Kamburico), Fedweb (Webster), Warigo (Hope) and Festival (Kenya 744 C6041).

Origin of the New Rusts.

There is no satisfactory explanation to account for the occurrence of these new rusts in either the leaf rust or the stem rust groups. There are several alternative suggestions. The role of the alternate host is well known, but in Australia this is probably only of minor importance. It is obvious that we must look for other causes and the work of Nelson and Wilcoxon (1954) needs further investigation.

In addition to the doubt concerning the mode of origin of these new types found in field collections, there is no proof to establish clearly that they are a recent development. There is a distinct possibility that they have been in existence for long periods. It may be that they are formed anew from the predominant types in each year of extensive rust development. In fact, if we agree that the changes in virulence are due to certain nuclear phenomena in the fungus, there is no reason to suggest that the rate of this change has been accelerated in the last thirty years, the period during which breeding for rust resistance has been in progress. All that has happened during this time is that the substrate has been repeatedly altered on a large scale, such that the virulence changes can be picked up with the sampling techniques adopted. It will be generally agreed that the sampling has been inadequate but under the circumstances it had to suffice. We have attempted to supplement it by growing specific indicator varieties at selected sites for observation. Except for showing the distribution of existing types this procedure has not helped to any extent.

Techniques for Detecting New Rusts.

In an earlier publication (Watson and Singh, 1952) it was suggested that the presence of certain rusts could pass unnoticed when using the techniques commonly employed in rust surveying work. We considered it useful to know the designation and distribution of the various races in a given geographical area, but we believed it more important to expose all available sources of resistance to as much rust as possible. In this way the breeding work could be more closely related to the rust survey studies. It is clear from our present knowledge that when the crosses that resulted in Eureka, Kendee, Gabo and Festival were planned, the respective resistant parents Kenya 743 (C6040), Kenya 745 (C6042), Gaza and Kenya 744 (C6041) should have been included in the set of varieties on which all rust collections for identification were placed. This would have given a greater opportunity to detect, if present, those rusts that have ultimately turned up to render susceptible Eureka, Kendee and Gabo.

Any procedure which enlarges the group of differential varieties increases the work and this must be weighed against the added information gained. We have done this and since 1952 seedlings of the following varieties have been included along with most of Stakman's varieties in the race survey work: Yalta, Eureka, Eureka × (Eureka × Gabo), Kenya 117A, Bokveld 1224, Khapli derivative 1451, Timopheevi derivative 1656, Agropyron derivative 1960 and Celebration.

From genetical studies something can be said of the genes possessed by certain of these varieties. Yalta has the resgene Kc_1 (Athwal and Watson, 1954) effective against the Australian rusts to which Gabo, Charter and Kendee are also resistant. Eureka has the gene Ka_1 which it has inherited from Kenya 743 C6040. Against certain Australian rusts this gene is highly effective, giving almost immune reactions at 60°F. As the temperature increases to 75°F. it becomes completely ineffective and thus to these same rusts Eureka becomes fully susceptible. Eureka × (Eureka × Gabo) is a line derived to help the spread of race 222BB in the field. It combines the genes Ka_1 and Kc_1 and hence is specific for those rusts attacking both Gabo and Eureka. It distinguishes

between those epidemics caused by race 222BB alone and those caused by a mixture of races 126B and 222AB. Kenya 117A has the gene Kb_1, effective against all Australian stem rusts so far recorded. This gene appears to be allelic with the gene in Kenya 744 (C6041) which has been transferred to Festival. It may be identical with it (Athwal and Watson, 1954). Kb_1 appears to be allelic also with the gene in Egypt NA95 1228 (Athwal and Watson, unpublished). Bokveld has been included among the set since it is useful for the differentiation of rusts at high temperatures when Ka_1 is ineffective. From limited studies only the gene serving this useful purpose appears to be allelic with or closely linked to Ka_1, so that at low temperatures there is no segregation in crosses between Eureka and Bokveld. It is expected as a result of further work that a derivative of Bokveld may replace Eureka in this group of varieties. KD1451 has inherited two genes from Khapli Emmer (Athwal, unpublished) but they are not equally effective. TD1656 from Wisconsin, U.S.A., possesses two linked genes which have been effective against all Australian rusts recorded. AD1960 was derived by Dr. Shebeski in Canada, and to Australian rusts it appears to show the presence of several factors concerned in resistance. Celebration has inherited its resistance from Marquillo. It lacks the immunity factor possessed by Thatcher to those races unable to attack Kanred (Athwal and Watson, in press) and in general has a lower seedling resistance than Marquillo to the common rusts. Hope, while a useful parent in breeding, has not been found suitable for glasshouse work.

Designation of New Rusts.

The main details of the frequency of the various rusts determined in this work up to date will be given elsewhere, but during 1954–55 three new types were detected. The significance of two of them could have been overlooked in the absence of the results obtained on the sources of resistance. The relationship of these to the other common rusts detected during this period is shown in Table 1. As pointed out by Watson and Singh (1952), one set of differential genes would probably serve for the whole of Australia, and from Waterhouse's studies, extending over many years, it is likely that the same set would also serve New Zealand. Since there appears to be an interchange of spore material across the Tasman Sea, these two countries would constitute one geographical area. In view of this, it is proposed to specify the area from which these rusts came by using the letters Anz in their designation. Such a system would be in line with that commonly used elsewhere.

From Table 1 it will be clear that races 21, 126 and 222 have been found. The latter two can be subdivided into biotypes by the inclusion of the varieties given above. Thus there are three biotypes of race 126 and four of race 222. So far only one type of race 21 has been found, although the work on this is still unfinished. It is apparent from this table that under Australian conditions a study of the biotypes assumes greater importance than a study of the races, and this is inevitable since the genes present in the varieties of Stakman's set have played no part in the evolution of local stem rust resistant selections.

Of the eight rusts recorded in Table 1 it will be seen that all but three have been given designations by Waterhouse, and even race 21 has been recorded by him for Australia. However, as he does not give its reactions or varieties beyond Stakman's set it cannot be assumed to be identical with 21 Anz 1 and his culture was not available for comparison.

This rust 21 Anz 1, the first of the three new ones, is typical of race 21. It differs from the other two common Australian races, viz. 126 and 222, by its virulence on the *T. durum* varieties in the set at low and high temperatures. From the plant breeding viewpoint, however, its significance lies in the ability to attack Marquillo and Celebration, the latter being cultivated commercially and formerly being resistant to all Australian rusts. Although no rust capable of attacking Marquillo seedlings has been found previously, this is possibly because neither Marquillo nor Celebration has been included among the differentials. Race 21 gives an immune reaction on Kanred and, if it should be sent in mixed with 126 or 222, it could easily pass unnoticed, since the immune reaction on Kanred would not be evident.

During the 1954–55 survey, 21 Anz 1 was so widespread throughout eastern Australia that it must be concluded that this rust has been present for some time. Waterhouse recorded it first in 1948 from Kosciusko, and although it has not been found since it is possible that it has been on the increase. Very little rust was collected in 1953–54, when the writer first undertook this work, and race 21 was not among the types determined. It has only become obvious with the inclusion of Celebration among the differentials. Race 21 Anz 1 has been recorded most frequently from the southern portion of eastern Australia, but the following localities from which it has come indicate its widespread distribution:

New South Wales: Barmedman, Barham, Baradine, Curlewis, Corowa, Cowra, Forbes, Muttama, Narromine, Numba, Parkes, Scone, Tullibigeal, Uralla, Wagga, Wallendbeen, Walcha, Willow Tree, Woodstock, Young.

Queensland: Benowa, Warwick.

Victoria: Rutherglen, Lockwood, Longeronong, Burnley Gardens.

Tasmania: Launceston.

It has not been sent in from South Australia or from Western Australia.

TABLE 1.

Races and Biotypes of Puccinia graminis tritici *Detected during the 1954–55 Rust Survey on Stakman's Differentials, Australian Differentials and on Various Sources of Resistance.*

Race No.	Differentiating Variety.																						Waterhouse Designation.
	Little Club.	Marquis.	Kanred.	Kota.	Arnautka.	Mindum.	Spelmars.	Kubanka.	Acme.	Einkorn.	Emmer.	Khapli.	Yalta.	Eureka.	Gabo × Eureka.[a]	Bokveld.	Kenya 117A.	AD 1960.	KD 1451.	TD 1656.	Marquillo.	Celebration.	
21 Anz 1 ..	4	4	0	3	4	4	4	3+	3+	;	;	;	;	;	;	;	2=	;	1+	x=	3	3+	—
126 Anz 1 ..	4	4	3	3	x	x	x	x	x	;	;	;	;	;	;	;	2=	;	1+	x=	;	x−	126
126 Anz 2 ..	4	4	3	3	x	x	x	x	x	;	;	;	;	3+	;	3−	2=	;	1+	x=	;	x−	126B
126 Anz 3 ..	4	4	3	3	x	x	x	x	x	;	;	;	3+	;	;	;	2=	;	1+	x=	;	x−	—
222 Anz 1 ..	4	4	3	3	x	x	x	1	1	;	;	;	;	;	;	;	2=	;	1+	x=	;	x−	222
222 Anz 2 ..	4	4	3	3	x	x	x	1	1	;	;	;	3+	;	;	;	2=	;	!+	x=	;	x−	222AB
222 Anz 3 ..	4	4	3	3	x	x	x	1	1	;	;	;	3+	3+	3+	3−	2=	;	1+	x=	;	x−	222BB
222 Anz 4 ..	4	4	3	3	x	x	x	1	1	;	;	;	3+	3+	3+	3−	2=	;	1+	3+	;	x−	—

In most cases the rusts from New South Wales were collected by co-operating farmers and on varieties other than Celebration. The samples from elsewhere came from research station workers. In those cases in New South Wales where rust was forwarded on Celebration plants it proved to be 222 Anz 2 and 3. At Myrtleford, Victoria, Mr. P. H. Debrett found rust on Celebration but none on Thatcher and, although no viable uredospores were available, these readings probably indicate that 21 Anz 1 was present, since Thatcher is known to possess the immunity factor to rusts of this type (Athwal and Watson, in press). Moreover, adult plants of Celebration have been found to be susceptible in the glasshouse to this rust. It will be seen from Table 1 that several sources of resistance are still effective despite this new rust. Ka_1, Kc_1, Kb_1 are all useful and the genes of KD1451, TD1656, AD1960 and probably Hope can still be of value.

The second new rust, 222 Anz 4, may turn out to be of less practical importance than the first. It is closely related to race 222BB (222 Anz 3) already described by Waterhouse, and it may have arisen from it. The material which carried this rust came from Richmond, N.S.W. At this centre a heavy stem rust epidemic caused almost entirely by 222 Anz 3 had been created artificially in an isolated area by inoculation of spreader rows with a pure culture.

Genetic material of the cross Eureka × TD1656 was being studied under this epidemic. Crosses in which TD1656 is the resistant parent usually show a two-class

segregation which is in agreement with a hypothesis suggesting two linked factors. However, in crosses with Eureka the data suggest other possibilities. Here the ratios are complicated by the fact that some plants show the presence of 1–2 pustules of a susceptible type. It was from these anomalous reactions that the rust was collected. Such anomalous reactions had been observed in the same cross with 222 Anz 3 in the previous year at Castle Hill, but the rust causing them had not been tested in the glasshouse.

On Stakman's varieties it proved to be race 222 and 222BB by adding Eureka and Yalta according to Waterhouse's scheme. However, all isolates of 222 Anz 3 from field collections have in the past behaved similarly on the sources of resistance, i.e. on Kenya 117A, TD1656, KD1451, AD1960 and Celebration. However, to this rust 222 Anz 4, TD1656 seedlings were clearly susceptible. Steinwedel × *T. timopheevi* material from a cross originally made by the late Mr. J. T. Pridham was also susceptible in the seedling stage. At Richmond, however, no rust was found on adult plants of this material, of TD1656, or of *T. timopheevi*, and the explanation must await further study.

The third rust, 126 Anz 3, is only of passing interest. It closely resembles the 126 and 126B originally described by Watson and Waterhouse (1949) and listed as 126 Anz 1 and 126 Anz 2 respectively. All sources of resistance show similar reactions to these three biotypes of race 126.

Conclusions.

Breeding for rust resistance can only be done on a sound basis if the information on the variability of the organism is complete. As a result of the findings reported herein it is apparent that the programmes in eastern Australia will have to be modified, since Marquillo, which has been a source of resistance, is now ineffective. To rust 21 Anz 1 there are still several useful resistances available. Among these are KD1451, TD1656, AD1960, Kenya 117A and probably Hope. Work already done with these will be unaffected by the occurrence of this new rust.

Race 222 Anz 4 is much more virulent than 21 Anz 1 in that it has a wider host range. It represents the type of rust that can be defined as a step mutation. It possesses all the virulence factors of 222 Anz 3 but its pathogenicity has been increased one step further, as shown by the susceptibility of seedlings derived from *T. timopheevi*. The future of these derivatives as a source of resistance cannot be decided until the reaction of adult plants is definitely established. No rust has been found on them so far. Should they remain resistant, then it is clear that an independent genetic system must be responsible, since close correlation has been found to exist between seedling and adult plant reaction of crosses involving TD1656.

It follows that despite the occurrence of new rusts several resistances are unaffected and this demonstrates again the value of genetic diversity in the parents used in breeding for disease resistance.

Acknowledgements.

It is a pleasure to acknowledge the help given in this work by my colleagues Dr. E. P. Baker and Mr. D. S. Athwal. Thanks are due also to various members of the laboratory staff who have helped in the inoculations from time to time. Financial help has been given by the Flour Mill Owners' Association and is gratefully acknowledged.

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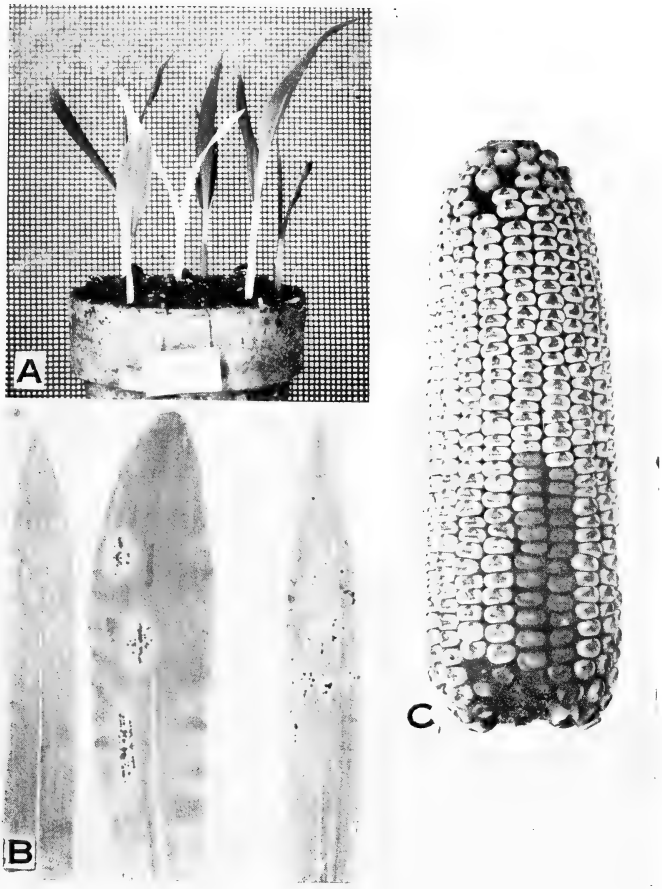
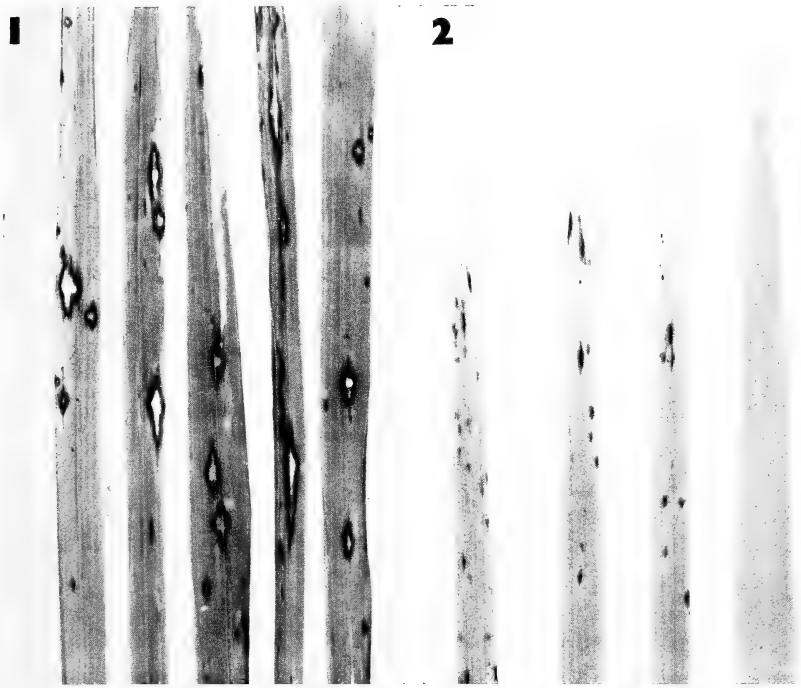
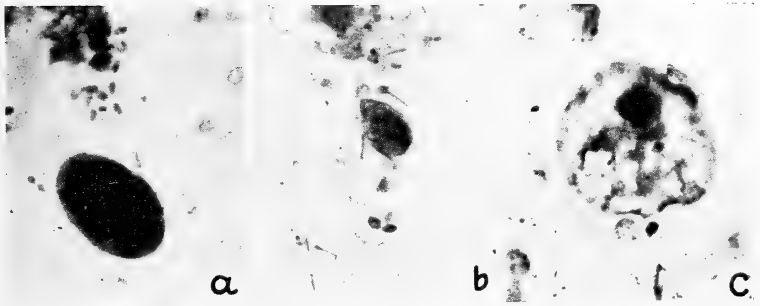


Rust of maize caused by *Puccinia sorghi*.



A. Diseases of Rice in Australia—1, brown spot; 2, rice blast.



B. Protozoan Populations in Soils—*a*. ciliate; *b*. flagellate; c. amoebae.

NOTES ON AUSTRALIAN FUR-MITES (LISTROPHORIDAE, ATOPOMELINAE), WITH DESCRIPTION OF A NEW GENUS.

By Robert Domrow,
Queensland Institute of Medical Research, Brisbane.

(Thirty Text-figures.)

[Read 28th September, 1955.]

Synopsis.

Five new species of a new Australian genus of fur-mites, *Cytostethum*, are described from a rat-kangaroo. Keys are given to the genera of Atopomelinae and the species of *Cytostethum*. *Campylochirus queenslandicus* (Wom.) n. comb. is redescribed. New synonymy: *Austrochirus* Womersley, 1943, equals *Campylochirus* Trouessart, 1893.

The fur-mites described in this paper belong to the group of genera of Listrophoridae (Sarcoptiformes), which have their anterior two pairs of legs modified to grasp the hair of the host, but not to the extent that the ambulacral apparatus is entirely lost. Gunther (1942) erected the subfamily Atopomelinae for these genera. As will be seen from the key below, the subfamily occurs on all the continents, but only *Marquesania*, *Campylochirus* and *Cytostethum* are known from Australia.

E. L. Trouessart (1893) erected the genus *Campylochirus*, the following being a translation of his description. "Body depressed; rostrum well separated, not covered by an elongation of dorsal shield, and often showing a neck-like constriction; two anterior pairs of legs curved inwardly, the tarsi forming a hook, often swollen to a club or a ruff; caruncles small, readily damaged (in dried specimens or in mounting); dorsal shield often much reduced or absent. *Male* with legs IV swollen (as in *Analges* and related genera); with copulatory suckers. Epimera of thoracic region W-shaped, with rounded posterior loops, and very strong median strip (sternum); coxae III exposed, and supported by arc-like epimera in front of the genitalia. Lower 'lip' normal." I have been unable to find an illustration of this genus.

The diagnosis of *Austrochirus* Womersley, 1943, is "elongate, dorsally compressed [should read 'depressed'], with only an anterior chitinised scutum. Legs I and II curved inwards, and modified for grasping hair. Coxae in two groups, epimera meeting in midline in all pairs. Leg IV of male very much stouter than in female. Caruncles present on all tarsi". This diagnosis fits *Campylochirus* Trouessart exactly, and they are here considered synonymous. The hosts of the two genera also correspond. Trouessart described the type species, *C. chelopus*, from *Phalangista cooki* Desmarest (now called *Pseudocheirus convolutor* Oken) and mentioned an undescribed species from *Antechinus* (Vitzthum, 1941, lists this host as *Phascogale flavipes*). Womersley's two species (1943, 1954), *A. queenslandicus* and *A. sminthopsis*, were recorded from *Trichosurus vulpecula* and *Sminthopsis crassicaudata*, which also belong to the Phalangeridae and Dasyuridae. It is, indeed, possible that Womersley's type species is really the same as Trouessart's.

Hirst (1917) described *Chirodiscoides* as follows: "Anterior legs modified so as to form clasping-organs as in *Chirodiscus* Trouess. & Nn., but a small pulvillus is present on the tarsi of these limbs. Fourth leg of male longer than the others (but not swollen), and its tarsus is bent at the end to form a hook. Body of male not bifid at the end as is the case in *Chirodiscus*, but produced into a short unpaired process. There are no long hairs on the body." The genus is illustrated in Hirst (1922) and Baker

and Wharton (1952), and these data exactly fit specimens of *C. caviae* from the type host from England, in the South Australian Museum. Womersley (1943), who did not have access to the original papers, and Radford (1950) synonymized *Chirodiscoides* with *Campylochirus*. Vitzthum was not as definite, saying, in translation: "in the genus *Campylochirus*, which is not sufficiently known, the clasping organs are formed as in *Chirodiscoides*, and it is not impossible that *Campylochirus* and *Chirodiscoides* are synonyms". Baker and Wharton, however, retain both genera, and I believe them to be correct.

Key to the genera of Atopomelinae.

1. Body compressed; with clam-like accessory claspers between coxae II and III; leg IV of male enormous (insectivore, China) ..... *Atopomelus* Trouessart, 1917.
   Body depressed; without clam-like claspers; leg IV of male variable ..... 2.
2. All coxae separated medially; three dorsal shields present (rodents, Marquesas Is., and Australia) ..... *Marquesania* Womersley, 1943.
   Coxae I and II hollowed out, and meeting medially in sclerotized sternum ..... 3.
3. Legs I and II not markedly flattened or incurved; leg IV and tarsus IV of male normal; Coxa III (not coxa II as given by Womersley) with stout inner tooth (rodents, Africa) ..... *Listrophoroides* Hirst, 1923.
   Legs I and II strongly flattened and incurved; leg IV or tarsus IV of male modified; coxa III without inner tooth ..... 4.
4. Only one dorsal shield, which may be reduced or absent; leg IV of male enlarged; venter with copulatory suckers (marsupials, Australia; rodents, Africa and America) ..... *Campylochirus* Trouessart, 1893.
   Both sexes with three dorsal shields and without long terminal setae. Male with leg IV not swollen; with tarsus IV hooked apically, and with sub-apical caruncle; with large copulatory suckers on venter (guinea-pigs, Europe) ..... *Chirodiscoides* Hirst, 1917.
   Both sexes with three dorsal shields and with a pair of long terminal setae. Male with leg IV enlarged and swollen, with tarsus IV with apical caruncle; without large copulatory suckers on venter (marsupial, Australia) ..... *Cytostethum* n.g.

Cytostethum, n.g., (κυτωδης, hollow; στηθος, sternum).

The diagnostic characters and relationships of the new genus may best be seen from the above key.

The following characters are not generically diagnostic, but are common to all five species. They are listed here to avoid repetition. Body slightly depressed; dorsum with three shields; first dorsal shield with two anterior setae; legs I and II flattened and incurved, with semi-transparent, cuticular flaps; tarsi I and II with small caruncles, and retrorse, sclerotized knobs; coxae I and II meeting medially to form a cruciform sternum, hollowed out on inner surfaces, transversely striated, and with narrow, transparent, marginal flaps, the whole cavity being used to enclose a single hair; coxae II with sclerotized process on outer posterior surface; coxae III and IV separate, with distinct coxal apodemes; tarsi III and IV with uniform setation. Tarsus III with four ventral setae, two of which are stronger than the others (these setae are labelled A, B, C, and D in Text-fig. 3); seta B absent on tarsus IV; tarsi III and IV with a lateral internal seta, a distal internal, and a distal external seta; tarsus III also with strong, curved, apical seta, and tarsus IV with fine, proximal dorsal seta.

The five new species described below were collected on the fine, dorsal body hairs of two rat-kangaroos, *Potorous tridactylus* Kerr; the locality and dates are Mt. Nebo, S.E. Queensland, 24.ix.54, T. Lawton, and 17.i.55, G. C. Taylor. Mites were common on both specimens examined, each mite being attached to the base of a single hair by its modified anterior legs and coxae. No specimens were taken *in copula*; ova were present in three species, lying lengthwise in the hysterosoma.

Key to the species of Cytostethum.

1. Female ..... 2.
   Male ..... 6.
2. Third dorsal shield extended anteriorly, so that the transverse row of four setae is placed on this shield; end of hysterosoma with small, pointed tubercles; no cuticular annulations ventrally ..... *C. trachypyx.*
   Transverse row of four setae in band of cuticular annulations; end of hysterosoma without small tubercles; cuticular annulations present ventrally ..... 3.

3. Second dorsal shield very narrow medially; third dorsal shield with irregular outline; no sclerotized plate on venter of hysterosoma; stouter species, up to 2·7 times as long as wide ..... 4.
Second dorsal shield deep medially; third dorsal shield with regular outline; sclerotized plate usually present ventrally on hysterosoma; slenderer species, more than 2·95 times as long as wide ..... 5.
4. Setae B and D on tarsi III and IV notched apically; third dorsal shield narrower medially; end of hysterosoma not sclerotized ..... *C. charactum.*
Setae B and D on tarsi III and IV not notched apically; third dorsal shield deeper medially; end of hysterosoma heavily sclerotized ..... *C. pseudocharactum.*
5. A larger species, 850μ long; no median plate immediately behind coxae IV; third dorsal shield distinct ..... *C. promeces.*
A smaller species, 580μ long; sclerotized median plate usually present behind coxae IV; third dorsal shield with poorly defined margin, or occasionally absent ..... *C. nanophyes.*
6. Setae B and D on tarsus III notched apically; terminal body setae not as long as free portion of leg IV; intromittent organ short; a stouter species ..... *C. charactum.*
Setae B and D on tarsus III not notched apically; terminal body setae longer than free portion of leg IV; intromittent organ longer; slenderer species ..... 7.
7. Leg IV reaching well beyond apex of hysterosoma; without "claspers" near genitalia; a larger species, 750μ long ..... *C. promeces.*
Leg IV stumpy and not reaching apex of hysterosoma; with well-developed "claspers" near genitalia; a smaller species, 440μ long ..... *C. nanophyes.*

CYTOSTETHUM PROMECES, n. sp. ($\pi\rho o\mu\eta\kappa\eta\varsigma$, elongated).

Types: Holotype female, ten paratype females, three paratype males and two morphotype nymphs in Queensland Institute of Medical Research, Brisbane, and five paratype females and two paratype males in South Australian Museum, Adelaide. This species is the genotype of *Cytostethum*, n. g.

Female.

Dorsum (Text-fig. 9). A rather slender species, length 854μ, breadth 288μ. First dorsal shield merging into capitulum, with posterior margin strongly convex, less heavily sclerotized anteriorly and medially. Second dorsal shield closely juxtaposed to first, with posterior margin only slightly convex, less heavily sclerotized medially; with a seta in each antero-lateral corner. Third dorsal shield excavated and weakly sclerotized posteriorly, with eight paired setae. About fifteen cuticular annulations between second and third dorsal shields, with transverse row of four setae.

Venter (Text-fig. 18). Sclerotization of third dorsal shield continued weakly right around venter. About ten annulations ventrally behind coxae IV. A pair of setae placed near the ends of two long sclerotized lobes between coxae IV. Some specimens bear a single elongate ovum, 288μ long, 86μ wide.

Tarsi III and IV (Text-figs. 1 and 2) with all ventral setae rather long and slender.

Male.

Dorsum. Somewhat stouter than female, length 744μ, breadth 293μ. First and second dorsal shields similar to female, but third strongly sclerotized, covering all of pointed posterior end of hysterosoma, with about ten paired setae. Five annulations are present between second and third shields.

Venter (Text-fig. 10) with strongly sclerotized postero-lateral margins, with five pairs of setae. Intromittent organ strong and curved, with base between coxae IV, and flanked by a pair of setae.

Legs III and IV (Text-fig. 10). Leg III identical with female. Leg IV greatly enlarged, incurved and heavily sclerotized, with small flap on inner edge. Tarsus IV with small caruncle, and four setae.

Nymph.

Similar in shape to female, 802μ long, 272μ wide. Only one small, anterior dorsal shield present, the rest of the body being covered by annulated cuticle, with eighteen paired setae dorsally; pair of long terminal setae present; coxal apodemes of coxae III and IV joined medially to a longitudinal sclerotization as in male; otherwise legs and tarsi similar to female. This stage is rather similar to the adult of *Campylochirus.*

CYTOSTETHUM TRACHYPYX, n. sp. (τραχυς, rough; πυξ, rump).

Types: Holotype female and two paratype females in Queensland Institute of Medical Research, and one paratype female in South Australian Museum.

Female.

Dorsum (Text-fig. 8). A stouter species, length 666μ, breadth 292μ. First dorsal shield not separated from capitulum, strongly convex posteriorly, separated from second dorsal shield by narrow furrow, which has a seta at each edge. Second dorsal shield with two posterior setae, and with posterior margin almost straight. Third dorsal shield extended anteriorly, with anterior margin almost straight, and posterior margin straight medially, with two lateral lobes; with four setae in addition to transverse row of four setae, which in the other four species is placed on the striated cuticle. Only five annulations between second and third dorsal shields. Posterior of hysterosoma with a pair of setae between lobes of third dorsal shield, with numerous small tubercles, and a blunt, dorsal, terminal process.

Venter (Text-fig. 17) with third dorsal shield encroaching laterally, with seta in each posterior corner; without cuticular annulations. Sclerotization complete between coxae IV, and without pair of small setae. One specimen with single egg, flattened on one side, and markedly curved on the other, 250μ long, 117μ wide.

Tarsi III and IV (Text-figs. 3 and 4) with setae rather shorter and stouter. Tarsus III high medially.

CYTOSTETHUM CHARACTUM, n. sp. (χαρακτος, notched).

Types: Holotype female, two paratype females, one damaged paratype male, and two morphotype nymphs in Queensland Institute of Medical Research. Four paratype females in South Australian Museum.

Female.

Dorsum (Text-fig. 7). A stout species, length 950μ, breadth 417μ. Capitulum separated from first dorsal shield, which is slightly concave anteriorly, and quite strongly convex posteriorly. Narrow furrow between first and second dorsal shields, with seta at each edge. Second dorsal shield irregularly concave anteriorly, and fairly straight posteriorly. About sixteen complete annulations between second and third shields, with transverse row of four setae, and a pair of setae near antero-lateral corners of third dorsal shield. Third dorsal shield strongly eroded marginally, with large posterior, median excavation, and eight paired setae. End of hysterosoma not sclerotized.

Venter (Text-fig. 16) with about fourteen complete annulations behind coxae IV. Third dorsal shield not encroaching on venter. With a pair of small setae on chitinized lobes between coxae IV.

Tarsi III and IV (Text-figs. 5 and 6) with setae B and D strongly sclerotized and notched apically. Setae A and C long and slender. Apices of tarsi III and IV with sclerotized, pointed process.

Male.

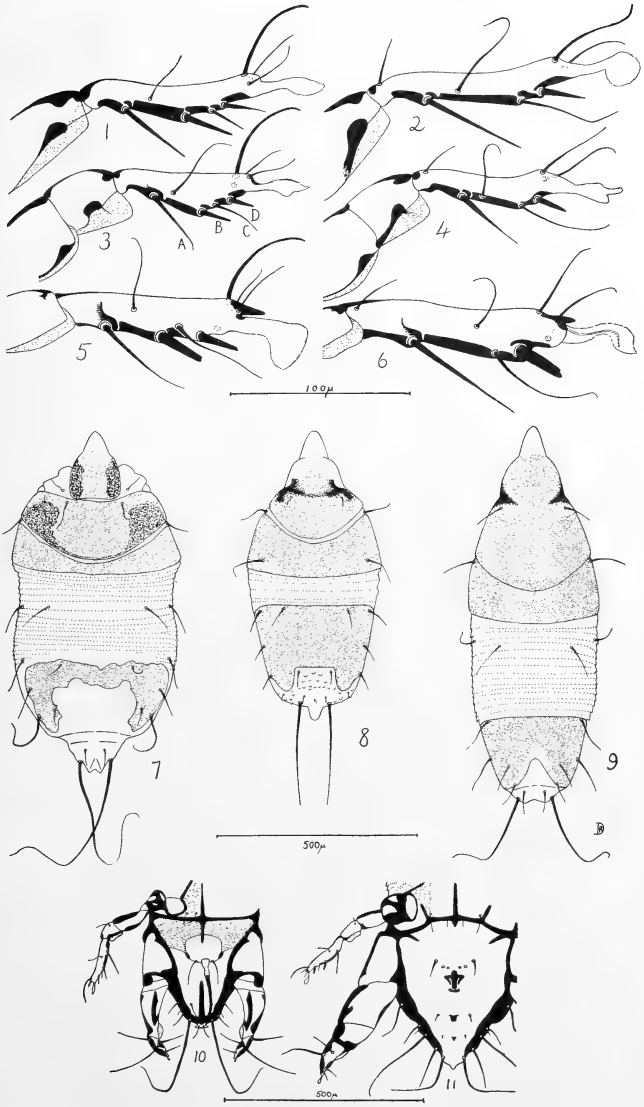
Dorsum. Stout, but no measurements are available as the single specimen is damaged. Anterior half of body similar to female. Third dorsal shield separated from second by about six annulations, and completely covering pointed end of hysterosoma as in *C. promeces*, with about ten paired setae.

Venter (Text-fig. 11) with strongly sclerotized postero-lateral margin, with six pairs of setae. Intromittent organ short, flanked basally by two pairs of small suckers and a pair of setae.

Legs (Text-fig. 11). Leg III identical with female, including notched setae B and D. Leg IV greatly enlarged, more than in *C. promeces*, incurved, heavily sclerotized, and with small flap on inner edge. Tarsus IV with small caruncle and four setae.

Nymph.

Very stout, length 630μ, breadth 366μ. Only one small, anterior dorsal shield, the rest of the body being covered by cuticular annulations. Pair of long, terminal setae



Text-figs. 1-6.—Inner ventral views of tarsi III (left) and tarsi IV (right) of female *Cytostethum*. 1 and 2, *C. promeces*; 3 and 4, *C. trachypyx*; 5 and 6, *C. charactum*.

Text-figs. 7-9.—Dorsal views of female *Cytostethum*. 7, *C. charactum*; 8, *C. trachypyx*; 9, *C. promeces*.

Text-figs. 10 and 11.—Ventral views of male *Cytostethum*. 10, *C. promeces;* 11, *C. charactum*.

present. Coxal apodemes of coxae III and IV as in nymph of *C. promeces*. Otherwise legs and tarsi similar to female.

CYTOSTETHUM PSEUDOCHARACTUM, n. sp.

Types: Holotype female and one paratype female in Queensland Institute of Medical Research, and one paratype female in South Australian Museum.

Female.

Dorsum (Text-fig. 19). A fairly stout species, length 850μ, breadth 348μ, very similar dorsally to *C. charactum*. About nine annulations between second and third dorsal shields, with transverse row of four setae. Third dorsal shield with eroded anterior edge, posteriorly with two lateral lobes as in *C. charactum*, but medially convex and deeper; with ten paired setae. End of hysterosoma heavily sclerotized.

Venter (Text-fig. 20) with about twelve complete striations. Pair of small setae on sclerotized lobes between coxae IV.

Tarsi III and IV (Text-figs. 14 and 15). Setae B and D rather short and not notched as in *C. charactum*; setae A and C fairly slender. Tarsus III with small, apical, sclerotized point.

CYTOSTETHUM NANOPHYES, n. sp. (*νανοφυης*, dwarfish).

Types: Holotype female and one paratype female in Queensland Institute of Medical Research. Also three female and five male paratypes in South Australian Museum, taken from same host, Tasmania, March, 1947.

Female.

Dorsum (Text-fig. 21). A small, slender species, length 584μ, breadth 156μ. First dorsal shield slightly concave anteriorly, and very slightly convex posteriorly, separated from second by narrow furrow, with a seta at each edge. Second dorsal shield similar in shape to first, but larger. With about six annulations and a transverse row of four setae between second and third shields. Third dorsal shield oval, without distinct margin, or entirely absent in one specimen, being replaced by transverse cuticular annulations. Posterior of body with pointed lobe.

Venter (Text-fig. 22). The specimens with the third dorsal plate present also have a sclerotized median plate behind coxae IV, with margin indistinct, and merging into annulations which run forward. This plate is absent in the specimen without a third dorsal shield. A sclerotized strip between coxae IV, with two small setae. Three specimens, including the one without a third dorsal shield, bear a single, elongate ovum, 203 to 234μ long, 47 to 62μ wide.

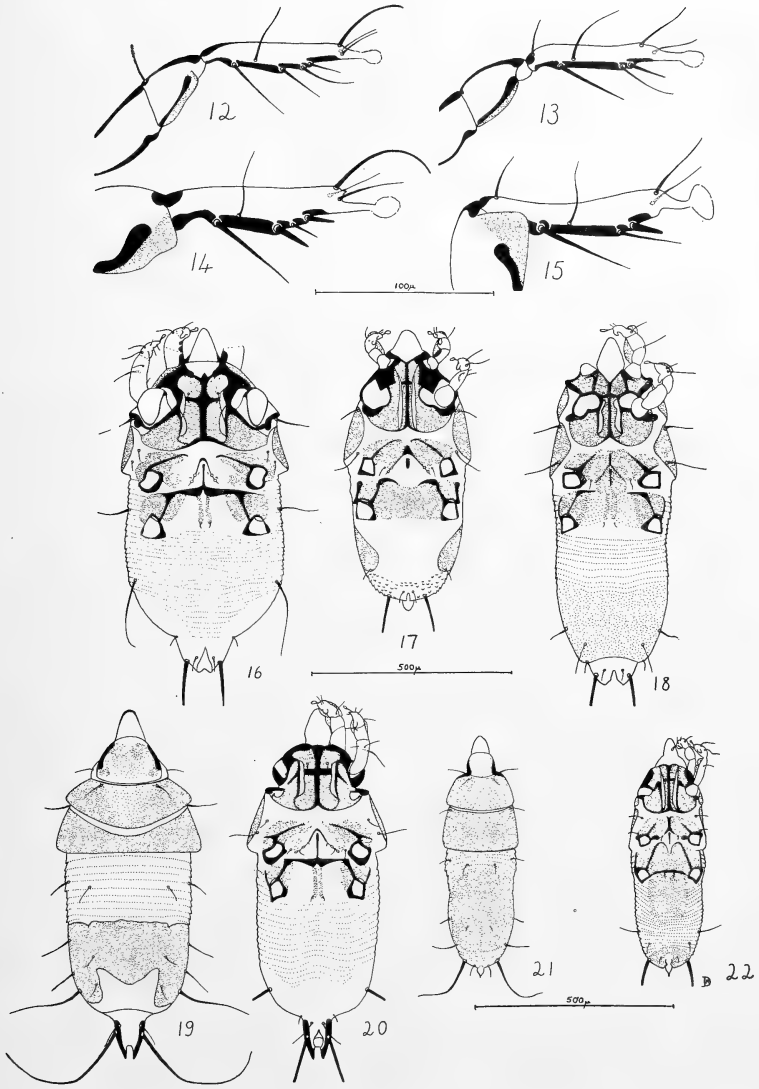
Tarsi III and IV (Text-figs. 12 and 13) with all setae, including B and D, long and slender.

Male.

Dorsum. Slightly stouter, but smaller than female, 436μ long. Anterior part of body as in female. Third dorsal shield reaching edge of hysterosoma and more heavily sclerotized than in female.

Venter (Text-figs. 29 and 30). Genitalia placed between coxae IV, flanked by two distally-expanded processes, which are attached to lobes of the sclerotization between coxal apodemes IV. These organs are possibly used as claspers, or to guide the intromittent organ. Anal area without suckers, and provided with four strongly sclerotized processes and two setae. Apex of hysterosoma transparent marginally, and with twelve paired setae, including one pair of very long ones. Beneath the cuticle between coxae III are six or seven spherical, translucent bodies of unknown nature.

Legs III and IV (Text-figs. 29 and 30). Legs III normal, with coxae III covered by sclerotized flap, apodemes of coxae III not meeting medially. (The flap over coxae III is not as prominent in the other four species.) Legs IV swollen and stumpy, apodemes of coxae IV meeting medially in cruciform sclerotization. Area around apodemes completely sclerotized and punctate. Penultimate segment of leg IV provided with stout inner spine almost as long as tarsus IV. Tarsus IV heavily sclerotized, with five



Text-figs. 12-15.—Inner ventral views of tarsi III (left) and tarsi IV (right) of female *Cytostethum*. 12 and 13, *C. nanophyes*; 14 and 15, *C. pseudocharactum*.

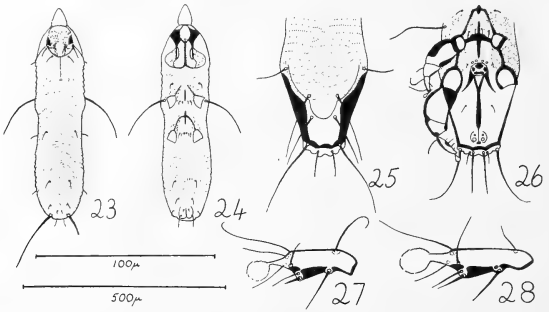
Text-figs. 16-18.—Ventral views of female *Cytostethum*. 16, *C. charactum*; 17, *C. trachypyx*; 18, *C. promeces*.

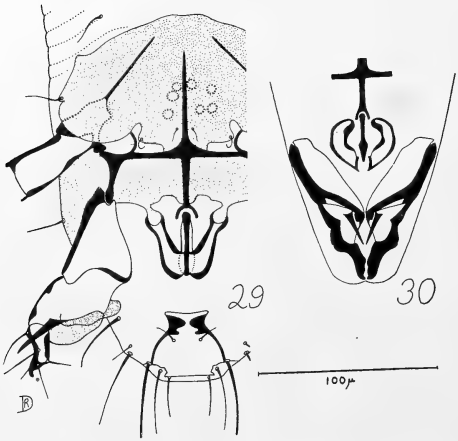
Text-figs. 19-22.—Dorsal (left) and ventral (right) views of female *Cytostethum*. 19 and 20, *C. pseudocharactum*; 21 and 22, *C. nanophyes*.

setae, and stout apical point. Caruncles not seen on tarsi IV. Text-figure 29 was drawn from a very flattened specimen in which the leg structure was easily seen. In the other four male specimens, which are not flattened, legs IV are folded inward, the hooks of the tarsi meeting medially (see Text-fig. 30).

Distribution.

All five species are known from the type host and locality in S.E. Queensland, and *C. nanophyes* also from the same host, Tasmania.





Text-figs. 23-28.—Dorsal and ventral views of female nymph (left) and mature male (right), and inner ventral views of tarsi of *Campylochirus queenslandicus*. 23 and 24, female nymph; 25 and 26, mature male; 27 and 28, tarsi III and IV of female.

Text-figs. 29 and 30.—Ventral surface of male *Cytostethum nanophyes*. 29, large, flattened specimen; 30, normal specimen with legs IV folded.

CAMPYLOCHIRUS QUEENSLANDICUS (Womersley, 1943), n. comb.

Recently fresh material of this species collected from *Isoodon obesulus* Shaw and Nodder (Flying Fish Point, N.Q., 22.iv.55, E. H. Derrick) has been seen. The type series has also been examined. Womersley's description and figures are incorrect in some respects, and the species is redescribed and refigured below. The dorsal shield in all stages is not uniformly sclerotized and punctate, and the four setae are actually off

the shield (Text-fig. 23). The inner surfaces of coxae I and II are definitely transversely striate.

Female adult.

Apart from the differences above, Womersley's figure and description are correct. The ovum is single, elongate-oval, with the capsule thickened and asymmetrical at the anterior end, 257μ long, 54·6μ wide.

Female nymph.

Dorsum (Text-fig. 23). A slender stage, varying in length from 468 to 480μ. With small antero-dorsal shield not sclerotized medially or at postero-lateral margins, and without setae, but with four setae just behind postero-lateral margins. Remainder of dorsum covered by cuticular annulations, which are more crowded posteriorly. Dorsum and sides of hysterosoma with twelve small, paired setae. End of hysterosoma with small triangular area without annulations, and with two long apical setae.

Venter (Text-fig. 24). With scale-like folds in cuticle and a short seta in front of coxae III and with long seta outside coxae III. Apodemes of coxae III not meeting medially; with four small setae between coxae III. Apodemes of coxae IV meeting in longitudinal sclerotized strut; with a pair of small suckers and two pairs of small setae between coxae IV. Annulations very irregular, with about ten paired setae.

Tarsi III and IV (Text-figs. 27 and 28) shorter and stouter than in *Cytostethum*, but of similar general build, with setae placed as shown. Tarsus III with extra apical seta.

Male nymph.

In both the type series and the series from Flying Fish Point, there are two forms with well developed male genitalia, which are identical apart from the heavier sclerotization and ornamentation of the posterior third of the dorsum of the hysterosoma. I feel that the 8-legged form described by Womersley is an unmodified male, his description being adequate apart from the characters noted above. The male form described below is fully mature, and with sexual modifications at the posterior end of the hysterosoma. Lawrence (1952) reported that a similar condition may occur in *Alabidocarpus* Ewing.

Male adult.

Dorsum (Text-fig. 25). Somewhat stouter than female, length 508 to 580μ. Anterior part of body as in female. Posteriorly, hysterosoma with rounded median lobe, which has no transverse annulations. The short striations at the edges of this lobe are longitudinal. With three pairs of long setae placed around the lobe as illustrated. Postero-lateral margins of hysterosoma sclerotized, with two long apical setae. Apex of body with transparent, six-lobed cuticular membrane, with four pairs of setae.

Venter (Text-fig. 26). Setae around coxae III as in female, but apodemes stronger, and meeting medially in short bar. Apodemes of coxae IV strong and curved, partly obscured by coxae III, and meeting in longitudinal strut; with four small suckers and two small setae between coxae IV. Genitalia placed between coxae IV, with four sclerotized structures in the aperture, and with four sclerotizations which run back from the aperture, the median two of which combine and run back to the level of the anus. One seta is present on either side of this median bar. Anus longitudinal, with two small suckers on each side, the anterior being the smaller. Postero-lateral margins of hysterosoma narrowly sclerotized.

Legs III and IV with tarsi rather similar to female, but tarsus III with small, inner, apical point. Other segments heavily sclerotized and swollen. (See Text-fig. 25.)

Acknowledgements.

I wish to thank Mr. H. Womersley for examining the specimens and confirming my belief that a new genus was needed. Mr. Hale has kindly allowed me to examine the type specimens of *Austrochirus queenslandicus* Wom., and *A. sminthopsis* Wom., and specimens of *Chirodiscoides caviae*, and to describe the male of *Cytostethum nanophyes* from the South Australian Museum collection.

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ACARINA FROM FIVE HUNDRED NATIVE MAMMALS FROM QUEENSLAND.

By Robert Domrow, Queensland Institute of Medical Research, Brisbane, and
D. J. W. Smith, Department of Health and Home Affairs, Brisbane.

[Read 28th September, 1955.]

Synopsis.

Thirty-nine species of mites and six species of ticks are listed from 582 native mammals of seventeen species collected in Queensland. Earlier partial lists are corrected, and eighteen new hosts recorded. New synonymy: *Laelaps melomys* Womersley, 1937, equals *Laelaps rothschildi* Hirst, 1914.

This paper is an extension of the small, recently published list (Domrow, 1954) of the acarine parasites of the introduced rats, *Rattus rattus* and *R. norvegicus*, in Queensland. The data on the Acarina collected on 582 native mammals from Queensland are now given. These animals form two series, one examined at the Department of Health and Home Affairs, Brisbane, between October, 1937, and September, 1941, and the second at the Queensland Institute of Medical Research, Brisbane, from June, 1950, to December, 1954. The Health Department series has unfortunately been partly destroyed, but careful examination of what is left, and the original notes and correspondence, together with the intact Institute collection, have allowed the compilation of the following list. The Health Department material was prepared by Dr. E. H. Derrick and one of us, D.J.W.S., while the Institute series was collected by Dr. Derrick, Mr. J. H. Pope, and the other, R.D.

Four small lists, devoted almost exclusively to parasites of bandicoots, have been published. The first (*Annual Report on the Health and Medical Services of the State of Queensland for the year 1937-38*) gave fourteen records. These included eight from bandicoots, of which all are correct except *Schöngastia dasycerci* Hirst, which specimens were later considered (Womersley, *in litt.*, 5.x.38) to be a complex of two species, *Euschöngastia perameles* and *Guntherana kallipygos*. Both forms of Listrophoridae are considered to be *Campylochirus queenslandicus*, which was described from *Trichosurus vulpecula*, and is also common on the bandicoot. "*Laelaps* sp.n." was based on a preliminary identification (Womersley, *in litt.*, 17.vi.38) as "probably a new species of *Laelaps*". In a later letter (5.x.38) he regarded these specimens as more closely related to *Hypoaspis*. However the specimens are now lost; they may have been a new genus of Hypoaspidinae (Womersley, in press) from the same host, *Trichosurus vulpecula*. *Laelaps melomys* is a synonym of *L. rothschildi*, and is discussed under that species. The other three records are correct.

This first list formed the basis of the second (Derrick *et al.*, 1939) of nine species from bandicoots, of which the first five are correct. The other four were taken directly from Womersley, *in litt.*, 5.x.38. *Hypoaspis perameles* and *Neoschöngastia isoodon* were manuscript names of Womersley, and were listed without descriptions. They are therefore *nomina nuda*. *N. kallipygos* was a premature publication of the name under which Gunther (1939*a*) described the species. "Listrophoridae, species *nova*" is considered to be *C. queenslandicus*.

The third list of seven species from three native animals (*Sixth Annual Report of the Queensland Institute of Medical Research, 1951*) is correct.

The fourth list (Mackerras, Mackerras and Sandars, 1951) of seventeen species from the bandicoot was a compilation from earlier lists, but also included three species which were not taken in the present surveys, namely, *Ixodes fecialis* Warburton and Nuttall,

Trombicula deliensis Walch, and *T. minor* Berlese. However, the larva of *T. minor* is unknown, and this record may refer to *T. hirsti* Sambon (see Womersley, 1952, p. 83).

These four lists are referred to below as Lists A, B, C and D respectively.

DERMANYSSIDAE.

Bdellonyssus da Fonseca.

Bdellonyssus bursa (Berlese).—This species was taken only once, on a bandicoot; 10 ♀♀, Taringa, Brisbane, 7.x.50, E.H.D. See List C.

Echinonyssus Hirst.

Echinonyssus validipes Domrow.—This species was described from *Potorous tridactylus*. See Domrow (1955*a*).

LAELAPTIDAE.

Hypoaspis G. Canestrini.

Hypoaspis, sp.n. (Womersley, in press).—There is some doubt as to the correct host of this species, as it was found walking actively over the bodies of *Thylogale wilcoxi* and *Isoodon obesulus*, which had been packed in the same bag.

Haemolaelaps Berlese.

Haemolaelaps marsupialis Berlese.—This species is common on bandicoots in S.E. Queensland, being taken on more than 40 of those examined. It is often present in large numbers, up to 80 specimens being taken on a single animal. The mites have a decided preference for the area around the hind-quarters, and are sometimes engorged with blood. There is a large preponderance of females over males, there being only two males in more than 90 specimens in the Institute collection. A large proportion of these females are gravid, bearing a single egg. This species was recorded under the ms name "*Hypoaspis perameles*" in List B (Womersley, *in litt.*, 17.iii.55).

Laelaps Koch.

Laelaps nuttalli Hirst.—This species was taken in number on eleven of eighteen *Rattus culmorum* from Benarkin, October, 1953. See List A for records from bandicoots. Two new host records are three *R. conatus*, Babinda, October, 1954, and *Melomys littoralis*, Innisfail, 18.iii. and 12.iv.54. It would seem that this cosmopolitan species, like *Notoedres muris*, is moving onto the native fauna.

Laelaps rothschildi Hirst.—This species was previously recorded (List A) as *L. melomys* Womersley, 1937. On close examination, the two syntypes and more than twenty other named specimens in the South Australian Museum, Adelaide, were found to be identical with *L. rothschildi* Hirst, 1914, and *L. melomys* is here placed as a synonym of that species. Womersley (*in litt.*, 13.iv.55) agrees with this finding. Dr. G. Owen Evans of the British Museum has examined the type specimen of *L. rothschildi* for us, and says this "agrees very well with the figure given by Hirst (1914). The 'sternal shield' is a compound structure comprising a moderately sclerotised sternal shield bordered by a strongly sclerotised endopodal shield". This is the case in the syntypes of *L. melomys*, and Womersley's figure of the sternal shield is not quite exact. The syntypes of *L. melomys* also have heavier sclerotizations between coxae IV similar to those shown in the figure of *L. rothschildi*. A large series recently collected from *Melomys littoralis*, the type host of *L. melomys*, also agrees exactly with *L. rothschildi*.

Numerous specimens, Innisfail, 12.x.38, and 56 ♀♀, Babinda and Innisfail, March to April, 1954, from *Melomys littoralis*; in numbers from 20 to 50 on *M. cervinipes*, Mackay, 22.vi.38, and Imbil, 19.viii.38; also numerous specimens on three *R. assimilis*, Imbil, 6. and 19.viii.38.

Laelaps sminthopsis Wom.—This species, only recorded from *Sminthopsis leucopus* from Victoria, has been taken on *Antechinus flavipes*, 13 ♀♀, Mt. Glorious, 6.viii.51. See Womersley (1954*a*).

Laelaps sp.n. Womersley, in press.—Taken in numbers up to 28 on two of three *R. assimilis*, Mt. Glorious, 6.viii.51, and Mt. Nebo, 3.x.53.

HETEROLAELAPS Hirst.

Heterolaelaps antipodianus Hirst.—This species, recorded (List A) from Woombye, 26.i.38, was also taken in small numbers from a third bandicoot, Nambour, 21.vii.38. It has not been met with since.

MESOLAELAPS Hirst.

Mesolaelaps anomalus Hirst.—This species was originally recorded from New Guinea. Specimens have been taken in the present survey on two bandicoots in North Queensland, 5 ♀♀, Mossman, 2. and 3.iii.54. Smears from red specimens of this species made by Dr. E. H. Derrick showed blood cells.

Mesolaelaps australiensis Hirst.—See Lists A, B and D for records of this species from bandicoots.

In the paper containing the two new species listed above (Womersley, in press), there is also a new genus and species of Laelaptidae from the bandicoot from Institute material.

IXODIDAE.

IXODES Latreille.

Ixodes fecialis Warburton and Nuttall.—This rather rare species is recorded in List C from *Antechinus flavipes*, 2 ♀♀, 1 larva, Dalveen, 27.vi.51. Also one specimen from *R. assimilis*, Mt. Glorious, 6.viii.51, and 2 ♀♀ on *R. culmorum*, Benarkin, 21.x.53.

Ixodes holocyclus Neumann.—Apart from bandicoots, which are favoured hosts, this species was taken on *Antechinus flavipes*, Mt. Glorious, 6.viii.51, on four *Trichosurus vulpecula*, Nambour, 9.vi.–5.vii.38, and on *R. assimilis*, Mt. Glorious, 3.ix.54. See all four lists, and Smith (1942).

Ixodes tasmani Neumann.—This species is also common on bandicoots. Two specimens were also taken on *R. assimilis*, Mt. Glorious, 6.viii.51. See List C.

HAEMAPHYSALIS Koch.

Haemaphysalis bancrofti Nutt. and Warb.—Four specimens from *Trichosurus vulpecula*, Nambour, 2.vii.38. See List A.

Haemaphysalis humerosa Warb. and Nutt.—The biology and material of this species are fully discussed by Smith (1941). It has not been as common in the later Institute series. Additional localities from *Isoodon obesulus* are Camp Mt., S.E.Q., 5.x.53, Mossman, 20.ii.–3.iii.54, and Mirriwinni and Flying Fish Point, N.Q., November, 1954.

Haemaphysalis spinigera var. *novae-guineae* Hirst.—See List A. Nine specimens from three bandicoots, Nambour district, 10.i. to 28.ii.38.

SPELEOGNATHIDAE.

BOYDAIA Womersley.

Boydaia derricki Wom.—This probably accidental record from *R. assimilis* is discussed by Womersley (1954*b*). Only a single specimen is known.

TROMBICULIDAE.

TROMBICULA Berlese.

Trombicula antechinus Wom. and *Trombicula thylogale* Wom.—Both these species were described from Institute material by Womersley (1954*c*). The former species has also been taken on *R. assimilis*, Mt. Glorious, 6.viii.51.

EUSCHÖNGASTIA Ewing.

Euschöngastia antipodiana (Hirst).—This species was described from *Rattus greyi*, Kangaroo Is., S. Aust. About sixteen larvae have also been taken from *Antechinus flavipes*, Cooloolabin, 10 and 12.i.38. See List A.

Euschöngastia cairnsensis (Womersley and Heaslip).—Apart from the original records, further specimens have also been taken in the ears of two *R. assimilis*, Mt. Glorious, 6.viii.51 and Mt. Nebo, 9.x.50, and on the perineal region of bandicoots.

Euschöngastia derricki (Wom.).—Womersley (1952) only recorded the original Health Department material, but further specimens have been taken on one of the type hosts, *R. assimilis*, Mt. Glorious, 6.viii.51.

Euschöngastia hirsti (Wom. and Heas.).—Described from *Melomys cervinipes*. No further specimens have been taken.

Euschöngastia innisfailensis (Wom. and Heas.).—A new host record for this species is *Isoodon obesulus*, Innisfail, 1.x.54, eighteen larvae on perineum.

Euschöngastia perameles (Wom.).—This species was also described from Health Department material, and has since been taken on twelve of the bandicoots examined at the Institute. It is the commonest trombiculid species so far encountered on native mammals in S.E. Queensland. The specimens listed as *Schöngastia dasycerci* Hirst in List A are really a mixture of this species and *G. kallipygos*. Despite its name, this species has never been recorded from the genus *Perameles*. Womersley originally intended to call it *Neoschöngastia isoodon*, but, owing to the premature publication of that name in list B, he described it as *N. perameles* after another genus of bandicoots (1939, p. 160).

Euschöngastia phascogale (Wom. and Heas.).—Apart from the original records, this species has also been taken on *Isoodon obesulus*, Brisbane, 3.viii.51.

Euschöngastia popei Wom.—This species was described from Institute material (Womersley, 1954*c*).

Euschöngastia queenslandica (Wom.).—See Womersley (1939) for material from rodents. This species was also present on twelve of the bandicoots of the Health Department series, Cowan Cowan, Moreton Is., April to August, 1939. A further locality from *R. assimilis* is Mt. Nebo, 3. and 9.x.53. These latter specimens were in the ears of the host.

Euschöngastia rattus (Wom. and Heas.).—Ten specimens have been taken on the type host, *R. assimilis*, Mt. Glorious, 6.viii.51.

Euschöngastia smithi (Wom.).—Only known from the type series from *R. assimilis*, collected by Health Department.

Euschöngastia trichosuri (Wom.).—Described from *Trichosurus vulpecula* from Health Department material. No further specimen has been taken.

Euschöngastia wongabelensis (Wom.).—Two larvae from *R. assimilis*, Mt. Glorious, 6.viii.51.

GUNTHERANA Wom. and Heas.

Guntherana kallipygos (Gunther).—The records of Womersley (1939) from Queensland are from Health Department material. Further specimens were taken from bandicoots in the Institute series. Numerous ova were taken attached to the hairs of one bandicoot, Mt. Nebo, 16.iv.53. These were in all stages of development, and similar to those figured by Gunther (1939*b*), a fully developed larva being visible in several. See note on *S. dasycerci* under *E. perameles*.

LEEUWENHOEKIIDAE.

ACOMATACARUS Ewing.

Acomatacarus sp.—A species of this genus occurs rarely on bandicoots in S.E. Queensland. Two specimens are in the Institute collection, Indooroopilly, Brisbane, 20.ix.51, and Mt. Nebo, 16.iv.53. See Derrick and Womersley (1954). However the specimens are not in good condition, and we hesitate to name them specifically.

ACARIDAE.

ACARUS Linnaeus.

Acarus siro L.—Numerous males and females from vicinity of pouch of bandicoot, Brisbane, 4.ix.50. This bandicoot had been in captivity for several months, and was moribund on examination, when the mites were found. This species is normally not a parasite.

SARCOPTIDAE.

NOTOEDRES Railliet.

Notoedres muris (Mégnin).—A further host record for this cosmopolitan species, which, like *L. nuttalli*, also seems to be moving onto the native fauna, is *R. culmorum*, Eidsvold, 10.viii.51, and Benarkin, October, 1953. In the three rats with this parasite the infested part was a scurfy area around the base of the tail and on the back.

LISTROPHORIDAE.

Campylochirus Trouessart.

Campylochirus queenslandicus (Wom.).—The original material was collected by the Health Department from *Trichosurus vulpecula*. See List A and Womersley (1943). This species also commonly occurs in large numbers on the bandicoot, particularly on the hairs around the scrotum and perineum. Several series, October, 1950, to February, 1951, and October, 1951.

Marquesania Wom.

Marquesania expansa f. *queenslandica* Wom.—The original material was collected at the Health Department from *Rattus youngi*. Further specimens have since been taken on *R. assimilis*, Mt. Glorious, 6.viii.51.

Cytostethum Domrow.

Cytostethum charactum Domrow; *Cytostethum nanophyes* Domrow; *Cytostethum promeces* Domrow; *Cytostethum pseudocharactum* Domrow; *Cytostethum trachypyx* Domrow.—These five species were described from *Potorous tridactylus*. See Domrow (1955*b*).

The following is a list of the 45 species of Acarina found on the 582 mammals examined. The number of each animal examined is in brackets.

DASYURIDAE.

Antechinus flavipes Waterhouse (4)—**Laelaps sminthopsis, Ixodes holocyclus, I. fecialis, Trombicula antechinus, *Euschöngastia antipodiana, E. phascogale.*

PERAMELIDAE.

Isoodon obesulus** Shaw and Nodder (425)— *Bdellonyssus bursa, Haemolaelaps marsupialis, ?Hypoaspis* sp. n., n. g. sp. n., *Laelaps nuttalli, Heterolaelaps antipodianus, Mesolaelaps anomalus, M. australiensis, Ixodes holocyclus, I. tasmani, Haemaphysalis humerosa, H. spinigera* var. *novae-guineae, Euschöngastia cairnsensis, *E. innisfailensis, E. perameles, E. phascogale, *E. queenslandica, Guntherana kallipygos, Acomatacarus* sp., *Acarus siro, *Campylochirus queenslandicus.*

Perameles nasuta Geoffroy (2)—*Euschöngastia phascogale.*

PHALANGERIDAE.

Trichosurus vulpecula Kerr (14)—*Ixodes holocyclus, Haemaphysalis bancrofti, Euschöngastia trichosuri, Campylochirus queenslandicus.*

MACROPODIDAE.

Aepyprymnus rufescens Gray (3)—Nil.

Potorous tridactylus Kerr (2)—*Echinonyssus validipes, Cytostethum charactum, C. nanophyes, C. promeces, C. pseudocharactum, C. trachypyx.*

Thylogale wilcoxi M'Coy (1)—*?Hypoaspis* sp. n., *Trombicula thylogale.*

MURIDAE.

Hydromys chrysogaster Geoffrey (17)—Nil.

Melomys cervinipes Gould (4)—*Laelaps rothschildi, Euschöngastia hirsti, E. queenslandica, Guntherana kallipygos.*

Melomys littoralis Lönnberg (17)—**Laelaps nuttalli, L. rothschildi.*

Rattus assimilis Gould (17)—**L. rothschildi, Laelaps* sp. n., **Ixodes holocyclus, *I. tasmani, *I. fecialis, Boydaia derricki, *Trombicula antechinus, Euschöngastia cairnsensis, E. derricki, E. popei, E. queenslandica, E. rattus, E. smithi, *E. wongabelensis, *Marquesania expansa* f. *queenslandica.*

Rattus conatus *Thomas* (25)—**Laelaps nuttalli.*

Rattus culmorum Thomas and Dollman (22)—*Laelaps nuttalli, *Ixodes fecialis, *Euschöngastia cairnsensis, *Notoedres muris.*

Rattus lutreolus Gray (8)—*Euschöngastia cairnsensis, E. derricki, E. queenslandica.*

Rattus youngi Thomas (18)—*Euschöngastia queenslandica, E. cairnsensis, Guntherana kallipygos, Marquesania expansa* f. *queenslandica.*

Thetomys gracilicaudatus Gould (2)—Nil.

Uromys caudimaculatus Krefft (1)—Nil.

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* Denotes species recorded from this host for first time.

** Total includes all animals previously listed as *Isoodon macrourus* or *I. torosus.*

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NEW SPECIES OF TERMITES FROM AUSTRALIA.

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(*Communicated by Mr. K. L. Taylor.*)

(One Text-figure.)

[Read 28th September, 1955.]

Synopsis.

Descriptions are given of the winged adult of *Ahamitermes pumilus* (Hill), of the queen and soldier caste of a new species of *Paracapritermes*, and of the winged adult and soldier castes of a new species of *Termes*. In addition, brief notes on the biology of all three species are included.

Introduction.

During recent years the collection of more than two thousand series of termites by officers of the Division of Entomology and the Wildlife Survey Section, C.S.I.R.O., has added much to our knowledge of the biology and distribution of many species, as well as revealing the presence of a number of undescribed species. The present paper describes two new species and the winged adult of a third species previously known only from the soldier caste.

Of the two new species, one belongs to the widely distributed genus *Termes*, which is represented in the Australian fauna by twenty-one described species.

The second is placed in the genus *Paracapritermes*, previously represented by only the one species, *P. primus* (Hill), found in North Queensland. The new species of *Paracapritermes* occurs in the south-western region of Western Australia and is therefore of considerable interest in that it extends the known range of the genus to the opposite side of the continent.

Ahamitermes pumilus (Hill), the winged adult of which is described below, was previously known only from New South Wales and is now recorded from Western Australia. Several other species of termites show this same type of apparently discontinuous east and west distribution, viz. *Tumulitermes apiocephalus* (Silvestri), *T. comatus* (Hill), *T. peracutus* (Hill), *T. recalvus* (Hill), *Amitermes colonus* (Hill), and *A. obtusidens* Mjöberg. However, it is likely that, in most cases at least, these wide distributional gaps are due to lack of collecting.

Genus Ahamitermes Mjöberg.

1920, Mjöberg, *Arkiv för Zoologi*, vol. 12, No. 15, p. 89 (gen.).

1929, Nicholls, *J. Roy. Soc. W. Aust.*, vol. 15, p. 20 (gen.).

1942, Hill, *Termites (Isoptera) from the Australian Region* (Melbourne), pp. 10, 14, 310, 361 (subgen.).

1949, Snyder, *Catalog of the Termites (Isoptera) of the World* (Washington), p. 130 (gen.).

The genus *Ahamitermes* was originally erected by Mjöberg in 1920, the generitype being *A. nidicola* Mjöberg. Mjöberg described only the soldier caste of this species and his generic description, therefore, only referred to this caste (the alate of *A. nidicola* was described by Hill in 1942). In 1929 Nicholls described the winged form and soldier of *A. hillii* and also gave the first generic description of the alate caste of *Ahamitermes*. When Hill monographed the Australian termites in 1942 he described a third species, *A. pumilus*, and reduced *Ahamitermes* to subgeneric status, at the same time giving revised descriptions of the subgeneric characters of the winged adult and soldier. Snyder (1949) again raised *Ahamitermes* to generic status and this view is accepted in the present contribution.

The subgeneric description of the soldier caste as given by Hill (1942) is still valid for this caste, but that of the winged adult needs revision, since Hill considered that the markedly enlarged apical segment of the maxillary palp was a valid subgeneric character. As will be seen from the description of the winged adult of *A. pumilus* given below, this is not so and accordingly this caste is redefined as follows:

Winged adult: Small, dark coloured. Head wide behind, narrowed anteriorly; antennae of 15 segments, 3rd segment shortest of all; mandibles with apical tooth distinctly longer than and widely separated from 2nd tooth. Eyes prominent and moderately large to large. Fore tibiae with two or three mid and hind tibiae with two apical spurs.

The genus is known only from the Australian continent and comprises the following species: *Ahamitermes nidicola* Mjöberg, 1920; *Ahamitermes hillii* Nicholls, 1929; *Ahamitermes pumilus* (Hill), 1942; *Ahamitermes inclusus* Gay, 1954.

Ahamitermes pumilis (Hill).

1942, *Hamitermes* (*Ahamitermes*) *pumilus* Hill, Termites (Isoptera) from the Australian Region (Melbourne), pp. 366-367, figs. 279-280 (description of nymph and soldier); biology; from New South Wales.

1949, *Ahamitermes pumilus* (Hill). Snyder, *Catalog of the Termites* (*Isoptera*) *of the World* (Washington), p. 131.

Winged Adult (*hitherto undescribed*). (Fig. 1, A.)

Head dark brown with a number of paler areas on the frons; postclypeus, labrum, thoracic and abdominal tergites light brown; basal segment of antenna light brown, the remaining segments much paler; sternites of abdomen light brown at sides, paling towards centre and towards posterior segments of abdomen. Wings with brown coloration along anterior border of radial sector and behind costal margin, remainder of wing membrane clear. Head, thorax, and abdomen with only a few, scanty, long hairs. Labrum about half as long as it is wide in the middle; postclypeus more than twice as wide as long, the anterior margin straight, or at most slightly concave, posterior margin strongly convex. Eyes large and prominent, subspherical. Ocelli broadly oval, separated from the eyes by less than their shorter diameter. Fontanelle very large, irregularly oval, with a well-defined groove running from the anterior margin to the clypeofrontal suture. Mandibles (Fig. 1, *B*) with apical teeth and 2nd tooth on left mandible narrow and acutely pointed, 2nd tooth on right mandible somewhat more rounded. A short supplementary tooth between 2nd and basal tooth on each mandible. Terminal segments of maxillary palps not inflated. Antennae relatively stout, 15 segments, 1st segment more than twice as long as 2nd, 3rd segment shortest and narrowest of all, 5th segment shorter than 4th or 6th, 7th–14th short and oval, 15th somewhat longer with bluntly conical tip. Pronotum narrower than the head, about twice as wide as long; anterior margin widely and shallowly concave with a small median notch; antero-lateral corners rather square; lateral margins almost parallel for about one-third their length, then converging evenly to the posterior margin, which is shallowly concave; a small hyaline spot present in each antero-lateral corner, and between them, in the anterior quarter of the pronotum, a narrow irregular hyaline marking about one-third the width of the pronotum. Posterior margin of meso- and metanotum widely and rather deeply concave. Costa and radial sector very dark, other veins faint and weakly developed except at base. Media in anterior half of wing with 2–5 branches; cubitus in median third of wing with 8–10 branches. Tibial spurs 2:2:2.

Measurements (50 specimens from four series): Length with wings, 8·75–10·50 mm.; length without wings, 4·50–6·00 mm.; head, to apex of labrum, long, 1·10–1·15 mm.; head, to clypeofrontal suture, long, 0·60–0·69 mm.; head, wide, 1·13–1·24 mm.; eyes, maximum diameter 0·34–0·40 mm.; ocelli, long, 0·11–0·12 mm.; fontanelle, wide, 0·15–0·19 mm.; pronotum, wide, 0·92–1·06 mm.; pronotum, long, 0·49–0·57 mm.; forewing, long, 7·00–7·40 mm.; forewing, wide, 2·15–2·35 mm.

Distribution.—NEW SOUTH WALES: Mt. Lindsay (near Queensland border), 15.vi.38, F. N. Ratcliffe, soldiers, workers, nymphs and one brachypterous neoteinic (TYPE SERIES for soldier); Mt. Arthur (near Wellington), 26.xi.49, E. H. Riek, alates. WESTERN AUSTRALIA: 9 miles S.W. of Daniell, 23.x.54, J. H. Calaby and F. J. Gay, soldiers, workers, and alates (TYPE SERIES for winged adult); 9 miles S. of Goongarrie, 27–28.x.54, J. H. Calaby and F. J. Gay, soldiers, workers, and alates; 7 miles S.S.E. of Southern Cross, 30.x.54, J. H. Calaby and F. J. Gay, soldiers, workers, alates, and apterous neoteinic female.

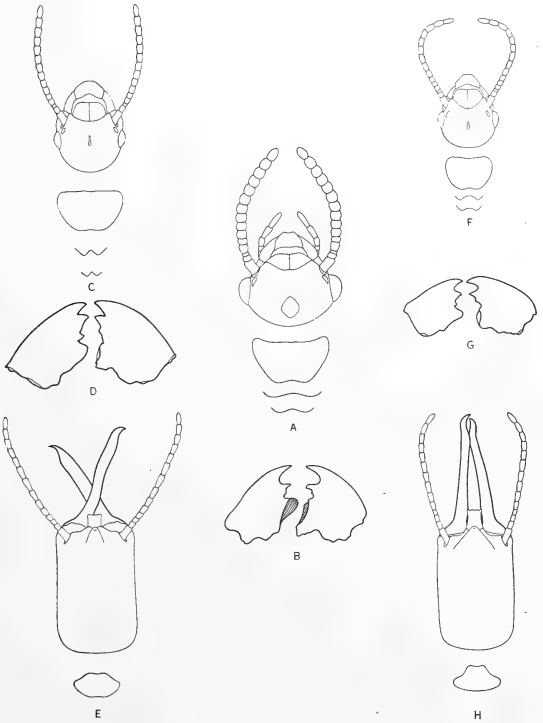

Fig. 1.—A: *Ahamitermes pumilus* (Hill), head and thorax of winged adult; B: mandibles of winged adult; C: *Paracapritermes hesperus*, sp. nov., head and thorax of queen; D: mandibles of winged adult; E: head and pronotum of soldier; F: *Termes iridipennis*, sp. nov., head and thorax of winged adult; G: mandibles of winged adult; H: head and pronotum of soldier. (Camera lucida drawings by Miss B. J. Gemmell.)

Biology.—The type series for the soldier caste is described by Hill (1942) as occurring in the "nursery and other galleries in a populous nest of *Coptotermes acinaciformis* in the interior of a living ironbark tree (*Eucalyptus paniculata*)". The three full series collected in Western Australia were all obtained from gallery systems restricted to the nursery region of nests of *C. acinaciformis* (Froggatt) in living eucalypts. The *Ahamitermes* galleries are constructed within the thin lamellae of the nursery, which, when broken open, are obviously darker in colour than the rest of the inner mound and nursery material. There is no evidence of any foraging gallery connection between the *Ahamitermes* colony and the outside of the mound, so that this species apparently is dependent on the *Coptotermes* colony for both shelter and food.

Winged adults are present in October and November, at the same time as those of its host species, and the evidence suggests that the alates of the two species leave the communal nest at the same time. This is supported by observations made on the Mt. Arthur (N.S.W.) series; these alates were collected at a light trap together with alates of *C. acinaciformis*.

Affinities.—*A. pumilus* is the most specialized species of the genus *Ahamitermes*, both in biology and morphology. In the soldier caste it is readily separable from the other described species by its smaller size, paler colour, and differently shaped pronotum. The alate caste differs from other described species in many characters, the most obvious of which are its very large fontanelle, non-pigmented wings, and the absence of swollen terminal segments on the maxillary palps.

Types.—Holotype soldier, morphotype winged adult female and worker in the Division of Entomology Museum, Canberra.

Genus Paracapritermes Hill.

1942, Hill, Termites (Isoptera) from the Australian Region (Melbourne), p. 416 (subgen.).

1949, Snyder, *Catalog of the Termites (Isoptera) of the World* (Washington), p. 190 (gen.).

Paracapritermes was proposed by Hill (1942) as a subgenus of *Mirotermes* (= *Termes*) to accommodate a species, *primus*, which, while possessing many of the characters of *Termes*, showed an important difference in the soldier caste, viz. the asymmetry of the mandibles. The material available to Hill did not include any winged forms, so that in defining the subgenus he dealt with the soldier only. When Snyder catalogued the termite fauna of the world (1949) he raised *Paracapritermes* to full generic status, and this concept is adopted here. With the material now available, together with the dealated adult of *primus*, it is possible to give a provisional definition of the winged adult.

Winged adult.—Small and hairy. Head rounded behind the eyes; fontanelle distinct, narrow. Eyes prominent. Antennae of 15 segments, 3rd segment shortest of all. Mandibles with apical tooth longer than 1st marginal; right mandible with two marginal teeth, left with three. Pronotum narrower than head; posterior margins of meso- and metanotum deeply and acutely notched.

Paracapritermes hesperus, sp. nov.

Winged Adult.

Not known.

Queen. (Fig. 1, C.)

A small species. Head, pronotum, and abdominal tergites light brown, antennae somewhat paler, postclypeus yellowish-brown. Head, thorax, and abdomen very hairy. Head shallow, very little narrowed anteriorly, almost semicircular behind the eyes, dorsal surface almost flat. Eyes prominent, 0·20 × 0·24 mm. diameter, ocelli small and oval (0·09 mm. long), separated from the eyes by less than their shorter diameter. Fontanelle narrow and linear, slightly swollen posteriorly. Mandibles (Fig. 1, D) with first tooth longer than second, two marginal teeth on right mandible, three marginal teeth on left; a deep anterior cut in advance of the 3rd marginal. Postclypeus 0·23 mm. long, 0·42 mm. wide, anterior margin almost straight, anteclypeus with strong median projection. Labrum narrow at base, widest in middle, apex very bluntly rounded. Antennae of 15 segments, 1st segment long and narrow, 2nd segment about half as long as 1st and narrower, 3rd segment shortest and narrowest of all, 4th segment longer than 5th and as long as 6th, 6th–14th increasing progressively in length, 15th ovo-conical. Pronotum somewhat narrower than head, anterior margin sinuate with median notch, anterolateral corners broadly rounded, lateral margins rounded and narrowed to the shallowly concave posterior margin; a small linear impression on each side and a little behind and parallel to the anterior margin. Meso- and metanotum markedly narrowed and deeply and acutely notched. Stumps of forewings conspicuously longer than those of hind wings.

Measurements.—Total length, 7·50 mm.; head to apex of labrum, long, 1·14 mm.; head to clypeofrontal suture, long, 0·62 mm.; head, wide, 0·92 mm.; pronotum, wide, 0·81 mm.; pronotum, long, 0·47 mm.

Soldier. (Fig. 1, E.)

Very variable in size, head pale orange-yellow, elongate, almost parallel-sided, sometimes slightly widened anteriorly. Frontal tubercle slightly corrugated, with long golden hairs, bent upwards at the apex; lateral processes absent. Right mandible stouter and somewhat shorter than the left, markedly curved but not twisted. Left mandible a little flattened and obviously twisted. Labrum fleshy, almost parallel-sided, anterior margin straight or with the antero-lateral corners slightly produced. Fontanelle concealed beneath the frontal process. Antennae 14-segmented, 1st segment stout and long, equal to 2nd and 3rd segments together, 4th–13th segments long and slender, 15th ovo-conical.

Measurements (50 specimens).—Total length, 4·50–5·60 mm.; head, plus mandibles, long, 2·45–3·48 mm.; head, to apex of frontal tubercle, long, 1·54–1·89 mm.; head, wide, 1·02–1·21 mm.; pronotum, wide, 0·57–0·73 mm.; pronotum, long, 0·29–0·40 mm.

Distribution.—Western Australia: Hester, 12.vii.38, M. F. Day, soldiers and workers; 12 miles N.N.W. of Arthur, 17.ii.53, J. H. Calaby, soldiers and workers; 13 miles S.E. of Armadale, 17.ii.53, J. H. Calaby, soldiers and workers; 6 miles E.S.E. of Karragullen, 27.ii.53, J. H. Calaby, soldiers and workers; 35 miles S.S.E. of Armadale, 3.iii.53, J. H. Calaby, soldiers and workers; 2 miles S. of Yornup, 4.iii.53, J. H. Calaby, soldiers and workers (Type Series for soldier); 4 miles W.S.W. of Boyup Brook, 4.iii.53, J. H. Calaby, soldiers and workers; 4 miles W.S.W. of Boyup Brook, 4.iii.53, J. H. Calaby, soldiers and workers; 2 miles N.E. of Pemberton, 5.iii.53, J. H. Calaby, soldiers and workers; 11 miles N.N.E. of Bindoon, 16.iii.53, J. H. Calaby, soldiers and workers; 1 mile N. of Prowaka, 16.iii.53, J. H. Calaby, soldiers and workers; 10 miles W. of Bilbarin, 3.iv.53, J. H. Calaby, soldier and workers; Corrigin, 3.iv.53, J. H. Calaby, soldiers and workers; 15 miles E. of Pindar, 21.vii.53, J. H. Calaby, soldier and workers; 1 mile N.N.W. of Maya, 22.vii.53, J. H. Calaby, soldiers and workers; 6 miles N.N.W. of Bullsbrook, 16.viii.53, J. H. Calaby, soldiers and workers; 8 miles E.N.E. of Jarrahdale, J. H. Calaby, 20.ix.53, soldiers and workers; 14 miles S.E. of Armadale, J. H. Calaby, soldiers and workers; 14 miles S.E. of Armadale, 20.ix.53, J. H. Calaby, soldiers and workers (two series); 16 miles S.W. of Beverley, 11.viii.54, J. H. Calaby, soldiers and workers; Dryandra, 15.ix.54, J. H. Calaby, soldiers and workers; 2 miles E. of Sawyers Valley, 5.iv.55, J. H. Calaby, soldiers and workers (two series); 4 miles N.E. of Kojonup, 10.v.55, J. H. Calaby, soldiers and workers; 20 miles N.W. of Williams, 26.vii.55, J. H. Calaby, soldiers, workers and queen (Type Series for queen).

Biology.—Of the twenty-five series so far collected, thirteen were found in galleries under old and embedded logs, some in association with other species of termites, viz. *Termes infrequens* (Hill), *T. kraepelinii* (Silvestri), *Coptotermes frenchi* (Hill), *Heterotermes ferox* (Froggatt), and *Microcerotermes serratus* (Froggatt). Two series were collected from galleries under stones, one being associated with *Occasitermes occasus* (Silvestri), *Heterotermes ferox*, and *H. platycephalus* (Froggatt). Two series were found in or under old stumps, one in association with *Amitermes modicus* (Hill), and five series occurred in mounds of *Amitermes obeuntis* (Silvestri), where they were associated with *A. modicus*, *T. kraepelinii*, *H. platycephalus*, *O. occasus*, *M. serratus*, *Coptotermes acinaciformis* and *Tumulitermes apiocephalus*.

Affinities.—The queen differs from the dealated adult of *P. primus*, *inter alia* by its somewhat larger size, paler colour, difference in the shape of the pronotum and by having the ocelli much closer to the compound eyes. The soldier is readily distinguished from that of *primus* by its larger size, larger frontal tubercle, more elongate antennal segments, and by the lesser twisting of the left mandible.

Types.—Holotype soldier, morphotype queen, and worker in Division of Entomology Museum, C.S.I.R.O., Canberra.

FERMES IRIDIPENNIS, sp. nov.

Winged Adult. (Fig. 1, F, G.)

A small species with brown head, thorax, and abdominal tergites; postclypeus and antennae grey-brown; wings pale brown (in living specimens the wings possess a beautiful steel-blue iridescence). Head, thorax, and abdomen clothed with numerous long hairs. Head semicircular behind the eyes, with an obvious depressed area surrounding the fontanelle. Postclypeus about two-thirds as long as wide, swollen and markedly bilobed, the anterior margin almost straight, the posterior margin strongly convex; anteclypeus with median region of anterior margin distinctly convex; labrum widest just behind middle, anterior margin shallowly concave. Fontanelle distinct, linear, narrowed anteriorly. Eyes moderately large and prominent, ocelli oval, their inner margins raised, separated by less than their shorter diameter from the eyes. Antennae 15-segmented, 3rd segment shortest and narrowest of all. Pronotum about two-thirds as long as wide, anterior margin shallowly concave, sides broadly rounded to the narrow, sinuate posterior margin; posterior margins of meso- and metanotum widely and deeply notched, the former more so than the latter. Media very close to the cubitus near the middle of the wing, either simple or with only a single branch; cubitus with 10–13 branches; wing membrane densely covered with micrasters.

Measurements (25 specimens).—Length with wings, 6·50–7·50 mm.; length without wings, 4·00–4·70 mm.; head, to apex of labrum, long, 0·88–0·95 mm.; head, to clypeo-frontal suture, long, 0·44–0·51 mm.; head, wide, 0·79–0·81 mm.; eyes, maximum diameter, 0·21–0·23 mm.; ocelli, long, 0·07–0·08 mm.; pronotum, long, 0·33–0·38 mm.; pronotum, wide, 0·60–0·69 mm.; forewing, long, 5·10–5·80 mm.; forewing, wide, 1·30–1·50 mm.

Soldier. (Fig. 1, H.)

Head and antennae orange-yellow; mandibles very dark reddish-brown, almost black; thorax and legs pale cream. Head elongate, almost parallel-sided, with a very slight constriction just behind the antennal insertions, postero-lateral corners rather square, posterior margin sinuate. Labrum elongate, sides slightly concave, the anterior margin sinuate or concave, the antero-lateral corners sometimes produced into short points. Frontal tubercle large, very stout at the base, bent up at apex (noticeably sharper than in *T. kraepelinii*). Mandibles long and slender, about as long as head capsule. Antennae of 14 segments, 4th shortest of all, 5th–14th elongate, increasing in length progressively.

Measurements (25 specimens).—Total length,* 4·50–5·20 mm.; head, with mandibles, long,* 2·67–2·98 mm.; head, to apex of frontal tubercle, long, 1·46–1·59 mm.; head, wide, 0·91–0·99 mm.; head, deep, 0·73–0·77 mm.; pronotum, long, 0·28–0·31 mm.; pronotum, wide, 0·54–0·57 mm.

Distribution.—WESTERN AUSTRALIA: 24 miles E. of Newdegate, 4.xi.47, T. Greaves and J. H. Calaby, soldiers, workers and alates; 15 miles N.N.W. of Mt. Ragged, 18.xi.47, T. Greaves and J. H. Calaby, soldiers, workers and alates; Balladonia Station, 20.xi.47, T. Greaves and J. H. Calaby, soldiers, workers and alates; 30 miles E. of Balladonia Station, 22.xi.47, T. Greaves and J. H. Calaby, soldiers, workers and alates; 9 miles S.W. of Daniell, 23.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates; 20 miles S.W. of Daniell, 23.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates; 21 miles W.N.W. of Kumarl, 23.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates; 5 miles N.W. of Norseman, 25.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates (TYPE SERIES); 23 miles N.N.W. of Widgiemooltha, 26.x.54, J. H. Calaby and F. J. Gay, alates; 7 miles W. of Coolgardie, 28.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates; 5 miles W.S.W. of Bulla Bulling, 29.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates; 11 miles N.W. of Southern Cross, 30.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates; 2 miles E. of Noongaar, 31.x.54, J. H. Calaby and F. J. Gay, soldiers, workers and alates.

Biology.—Thirteen series of this species are known, of which ten were collected from galleries at the base of, or in the outer clay wall of, mounds of *Coptotermes*

* With mandibles crossed at base.

acinaciformis. Of the remaining series, one was collected from galleries beneath a large log, where it was associated with *Schedorhinotermes reticulatus* (Froggatt) and *Microcerotermes newmani* (Hill). Winged adults are present in the colonies in October and November.

Affinities.—The winged adult is comparable in size with that of *T. infrequens*, also from Western Australia, but may be distinguished by its larger eyes, paler iridescent wings, and differently shaped pronotum. The soldier resembles that of *T. kraepelinii*, from which it may be distinguished by its shallower and relatively longer and narrower head and larger and sharper frontal tubercle.

Types.—Holotype winged adult female, morphotype soldier and worker in the Division of Entomology Museum, Canberra.

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A NEW GENUS AND TWO NEW SPECIES OF ACARINA FROM NORTHERN AUSTRALIA.

By H. Womersley, South Australian Museum.

(Two Text-figures.)

[Read 24th September, 1955.]

Synopsis.

A new genus and two new species of mites, *Steatonyssus malurus*, sp. nov. (family Macronyssidae) and *Cheletonata milesi*, g. et sp. nov. (family Cheyletidae) are described from the nest of the Red-backed Wren, *Malurus melanocephala*, from Beswick Creek, Northern Territory.

The following new species, *Steatonyssus malurus* (family Macronyssidae), and new genus and species, *Cheletonata milesi* (family Cheyletidae), were collected from a wren's nest by Dr. J. R. Miles, of the Medical and Veterinary Research Institute, Adelaide, while on an expedition to Northern Australia in November, 1954, in search of possible vectors of encephalitis.

Dr. Miles states that "the Wren's Nest was obtained about half a mile upstream along the creek from Beswick Creek Aboriginal Settlement. The nest was one recently used but containing neither eggs nor young. The appearances were those of a typical *Malurus* nest, i.e., a dome-shaped structure with the entrance high up in the side. It was made of grass and lined with fine material. It was 1–2 feet from the ground in a dense bush.

"The only *Malurus* present in the area was one family party with recently fledged young of the Red-backed Wren, *Malurus melanocephala* (Check List No. 541), and I think that it is reasonably certain that this bird had been the occupier the nest."

Family MACRONYSSIDAE Audemans, 1936.

Genus Steatonyssus Kolenati, 1858.

Kolenati, F. A., 1858, *Wien. Ent. Monatsschr.*, 2:5. Genotype by later designation *Steatonyssus musculi* (Schrk., 1803).

Steatonyssus malurus, sp. nov. (Fig. 1, A–D.)

Female. Shape oval, widest behind coxae IV. Length of idiosoma 650μ, width 455μ; length of gnathosoma 100μ. Dorsal shield distinctly divided as figured: anterior part or prosomal shield the smaller, 234μ long by 182μ wide, with the posterior margin straight, with seven pairs of fine setae, of which three pairs to 32μ long are on the disc, the others are lateral and to 40μ long; the posterior part or opisthosomal shield is 286μ long and 220μ wide with the anterior margin medially excavate, with five pairs of setae to 25μ long: the setae on the dorsum laterad of the shields are from 40μ long anteriorly to 80μ posteriorly. Venter: tritosternum as figured with apparently nude lacinia; no pre-endopodal shields; sternal shield short, arc- or band-like as in *S. viator* (Hirst), with three pairs of setae and two pairs of prominent lyriform pores; the setae are long and slender, the anterior pair 36μ long, the second pair 56μ and the third pair 70μ long, the ratio length:breadth of shield is ca. 0·12 (14μ long by 118μ wide); genital shield long and tapering to a point posteriorly, with one pair of setae; metasternal shields only represented by the setae; anal shield fairly large and pear-shaped with only the usual three paranal setae; on each side laterad of the genital and anal shields are ca. 14 setae. Legs not excessively long or thick and without any specialized armature beyond the dorsal tooth on coxae II; I, 480μ long; II and III, 440μ; IV, 500μ. Chelicerae simple, as figured. Peritreme slender, running from the stigma between coxae III and IV anteriorly to about coxae II, where it becomes dorsal.

Male. Unknown.

Locality and Host.—A number of specimens from a newly abandoned nest of the Red-backed Wren, *Malurus melanocephala*, from Beswick Creek, Katherine, Northern Australia, Nov. 11th, 1954 (coll. J. R. Miles).

Remarks.—In Zumpt and Till's "Key to the females of the Ethiopian species of *Steatonyssus*", 1954, the above new species comes very close to *S. reedi* Zpt. and Patt., 1952, in the form of the sternal shield and the straight posterior edge of the prosomal shield. The ratio length:breadth of the sternal shield is, however, much greater than in *reedi* (0·12 as compared with 0·09). In *reedi* the prosomal shield has nine pairs of setae as compared with only seven pairs in *malurus*, while on the opisthosomal shield there are six pairs as against five pairs in *malurus*.

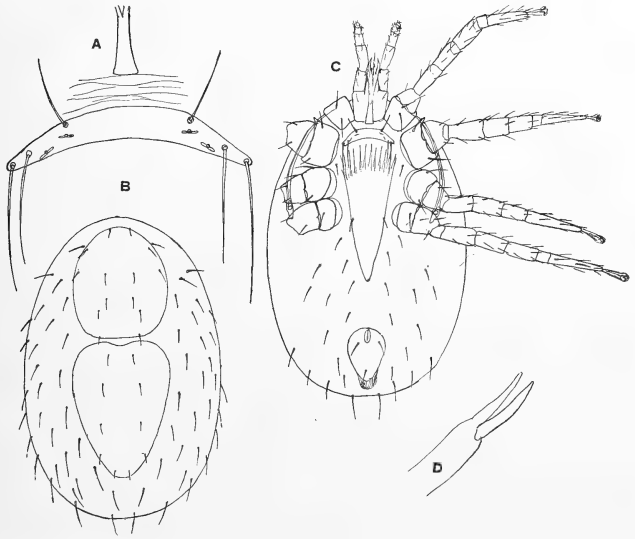

Fig. 1, A-D. *Steatonyssus malurus*, sp. nov. A: sternum together with base of tritosternum; B: dorsum; C: venter and right legs; D: chelicerae.

Family CHEYLETIDAE Leach, 1814.

Genus Cheletonata, nov.

Palpal tarsus with only one comb and two simple setae. With only one anterior dorsal shield. Dorsal and scutal setae fan-like. Leg I normal, ambulatory; tarsus with two small claws.

Genotype, *Cheletonata milesi*, sp. nov.

This new genus is closely allied to *Cheletonella* Womersley with *C. vespertilionis* Wom. as type (*Rec. S. Aust. Mus.*, 7(1): 60–61, fig. 7A–D, 1941). It differs in having only a single comb on the palpal tarsus, in the number of fan-shaped setae on the scutum and in being without similar setae on the palpal femur and genu. In the single dorsal shield and the palpal tarsus it will run down in Womersley's key (ibid., 51–52) to *Cheletopsis* Ouds., 1904, but differs from all known species of that genus in the shape of the shield and in the fan-shaped not long fine slightly ciliated setae.

Cheletonata milesi, sp. nov. (Fig. 2, A–C.)

Female. Shape broadly oval. Length of idiosoma 600μ, width 490μ; length of gnathosoma 170μ. Dorsally with only a single and anterior scutum slightly wider than long, shield-shaped, 210μ long by 220μ wide, anterior margin slightly incurved, lateral

margins rounded, with six pairs of fan-shaped setae to 45μ long; rest of dorsum with twelve pairs of such setae as figured. Eyes one on each side of and closely adjacent to the scutum. Gnathosoma large with prominent mandibles. Palpi large, stout and forceps-like; femur very stout with a long ciliated seta dorsally, ventrally with a rather long and nude seta on the disc and a smaller one apically; genu with a dorsal nude seta; tibial claw strong with four basal tuberosities; tarsus with only a single strong comb and two setae. Venter: coxae in two widely separated groups; a single pair of setae on coxae I and II, two such on III but apparently none on IV; a pair of setae between coxae II, coxae III and coxae IV; anus large, flanked on each side by three small setae; on extreme posterior margin is a single pair of small fan-like setae.

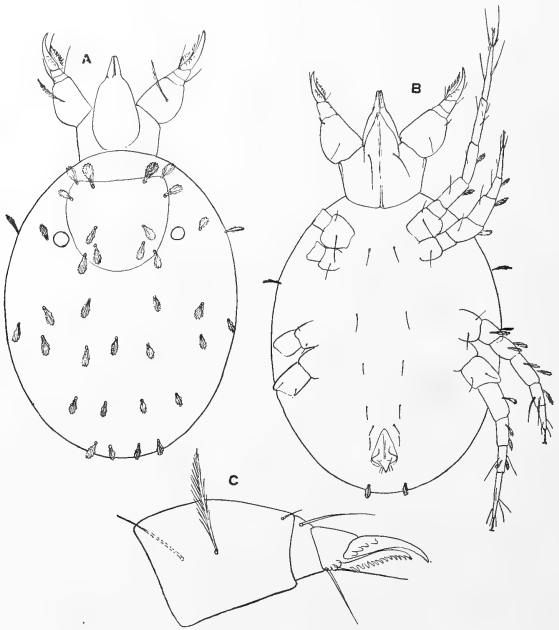

Fig. 2, A-C. *Cheletonata milesi*, g. et sp. nov. A: dorsal view of dorsum and gnathosoma; B: ventral view of same together with right legs; C: palp in dorsal aspect.

Legs: I, 490μ long, rather tactile looking but ambulatory with a slender caruncle and two fine claws; II somewhat stouter than I and 325μ long; III, 360μ, and IV, 490μ; there are fan-like setae dorsally on femur and genu of leg I, dorsally on femur, genu and tibia of leg II, dorsally and ventrally on trochanter, femur, genu and tibia of III, and on the femur, genu and tibia of IV.

Male. Unknown.

Locality and Host.—Five females from a recently abandoned nest of the Red-backed Wren, *Malurus melanocephala*, from Beswick Creek, Katherine, Northern Australia, 11th Nov., 1954 (coll. J. R. Miles).

Remarks.—This interesting species is dedicated to the finder who kindly submitted the material to the author. The types and paratypes of this and the preceding species are in the South Australian Museum collection.

PLEISTOCENE GLACIATION IN THE VICTORIAN ALPS.

By Stella G. M. Carr and A. B. Costin.

(Plates vii-viii; one Text-figure.)

[Read 28th September, 1955.]

Synopsis.

Evidence is brought forward to show that at least parts of the Victorian Alps have been glaciated.

The majority of the features described can be accounted for on the basis of a single glaciation, during which a névé-field developed and gave rise to cirque- and valley-glaciers.

It is suggested that glaciation in the Victorian Alps was probably contemporaneous with an early stage of the Kosciusko glaciations in New South Wales.

Introduction.

In the mountains of the west and south-west of Tasmania, and in the Snowy Mountains of New South Wales, a variety of evidence indicates that these areas were glaciated during the Pleistocene Epoch (Lewis, 1944; Browne, 1952; David, 1950).

In Tasmania the effects of three periods, or stages, of glaciation have been recognized. The Malanna glaciation was the earliest, and also the most extensive. It involved the formation of an ice-cap. During the second (Yolande) glacial period valley glaciers were formed. The succeeding Margaret glaciation was still more restricted, its main effects being the formation of small high-level cirques. Interglacial deposits of considerable extent and depth indicate that a long interval of time elapsed between the Malanna and Yolande glaciations. In this interval considerable river erosion took place. The distinctness of the Yolande and Margaret glaciations has not been clearly established. It is possible that the cirques attributed to the third glaciation may have been formed during the late stages of the Yolande period.

On the Kosciusko Plateau, the features so far studied indicate that the glaciations were similar in their general characters and effects to those of Tasmania, but it is admitted that conclusive evidence for the distinctness of the glacial periods in this area is lacking. However, it is reasonably assumed that the glaciations in both States were contemporaneous and, in the absence of evidence to the contrary, the periods have been tentatively correlated with the Mindel, Riss and Würm glaciations of Europe.

Previous Work in Victoria.

The discovery of evidence of Permo-Carboniferous glaciation by Selwyn in South Australia in 1859, and by Daintree at Bacchus Marsh in 1866, stimulated enquiry into the possibility of the occurrence in Australia of later glacial periods contemporaneous with those known to have affected the Northern Hemisphere. Investigation led to the more or less ready acceptance of the fact of Pleistocene glaciation in Tasmania and on the Kosciusko Plateau, although the details of the glacial topography in both areas have only been closely studied in comparatively recent years.

In Victoria, as in other States, there was an initial period of over-enthusiasm during which any smooth, jointed rock-surface was likely to be identified as a glacial pavement, any mass of boulders as a moraine, and any strange, large rock as an erratic boulder. The absurdity of many of the claims prejudiced acceptance, or even further investigation, of the few which now appear to have been reasonable. The result was that the idea that parts of Victoria may have been glaciated in Pleistocene times was completely neglected.

The first reference to Pleistocene glaciation in the Australian Alps was made by Clarke (1860). Writing of Muniong (somewhere on the boundary between New South Wales and Victoria, on or near the Kosciusko Plateau) he expressed the opinion: "Probably in earlier times glaciers did form, for I saw more than one *bloc perché*, a mass resting on upturned strata." On p. 230 he writes: "But I am persuaded that formerly true glacier ice was formed on Muniong, and I have always thought that the effect of it may have produced a *gold moraine* in places where auriferous veins came into contact with ice."

These statements formed the foundation for the further study of glaciation in New South Wales, but in Victoria little progress was made. Howitt (1879), who travelled widely in the mountainous regions of this State, wrote, "Nowhere in Gippsland have I been able to detect any appearances which I could in any way refer to a glacial period analogous to that of the Northern Hemisphere. I have nowhere met with grooved or scratched rocks, erratic boulders, moraines or any other traces of ice-action; and I think that had such existed they would have been met with ere this. Mr. Selwyn has, I believe, already noted this. The only features of the country which I think could in any way suggest glacial conditions are the apparently ancient lake-basins near Omeo."

Griffiths (1885) amplified Clarke's hope of finding a "gold moraine" into an ambitious theory. He stated that extensive Post-Miocene glaciation had occurred in Victoria, and that this had had important effects on the distribution of alluvial gold. The evidence brought to support the theory consisted mainly of re-interpretations of descriptions of physiographic and geological features culled from Brough-Smyth's "Goldfields of Victoria". Griffiths also, without apparent further investigation, took up Howitt's suggestion regarding the possible glacial origin of the lake-beds at Omeo and re-stated it as fact.

The importance of Griffiths to this discussion is that Stirling (1886 et seq.) was obviously greatly influenced by his theory. In fact, Stirling appears to have been temporarily so obsessed with the certainty of Pleistocene glaciation that he saw evidence for it wherever he looked.

He re-examined the valley of Livingstone Creek and claimed (Stirling, 1886*b*) to have found evidence to show that the former lake-basins were indeed of glacial origin. This idea, together with others regarding terminal moraines, glaciated pavements and the formation of the valley of the Victoria River at Cobungra, does not appear to have been taken seriously, either at the time of publication or subsequently. However, it was not until many years later that formal statements to the contrary were made. Thomas (1937), in discussing Lake Omeo, stated that no evidence of glacial action was seen in the area. Crohn (1947) showed that the formation of the lake-beds at Omeo was related to movements on the Livingstone Creek Fault.

It is probable that Stirling's other ideas regarding glacial features in the Omeo district are also incorrect. However, his record (Stirling, 1886*c*) of glaciated surfaces at elevations between 4000 and 6000 feet on the quartz porphyries of the Cobberas Mountains appears to be not entirely unreasonable. As far as can be ascertained, these surfaces have never been re-examined.

Lendenfeld, who had studied evidences of glaciation in New South Wales and New Zealand, was, in his day, regarded as an authority on the subject. Stirling accompanied him when he examined Mount Bogong, but, in spite of his earlier enthusiasm, was not convinced by the evidence collected, and commenced to doubt that Pleistocene glaciation had occurred.

Both Lendenfeld (1886) and Stirling (1886*c* & *d*) record smoothed and planed masses of rock on the lower slopes of the mountain. A mass of boulders at the 2000-foot level in the valley of Mountain Creek was identified by Lendenfeld as a moraine. Stirling was more cautious and wrote that these "large masses of angular and waterworn masses of rock are strongly suggestive of distributed or scattered moraines". Their difference of opinion was more acute concerning the origin of "large rounded and flattened masses of basalt-like rock" which they found. Lendenfeld states that most of these rocks are

"flattened on one side and some have smooth surfaces distinct from mere weathering". He says they are arranged "in a regularly descending series round the mountain at an elevation of 6000 feet and to lower levels". He identified the rock as "hornblendic quartz porphyrite" and, as he was unable to find any dykes *in situ* from which it might have come, put forward the idea that the boulders could have been transported by ice from Mount Nelse "at the northern extremity of the Bogong High Plains, some twelve miles distant to the south". Stirling obviously found it difficult to accept this. He writes: "Should these large boulders, now so strangely situated, prove on further examination of the mountain to be foreign to the locality, their origin is very inexplicable, even on the theory of glacier translocation. Situate at a higher level than the surrounding ranges, it is difficult to account for their presence, even by the convenient theory of glacier action . . ." Stirling does not mention the difficulty that Mount Bogong and Mount Nelse are separated by the very steep valley of the Big River (here 3000 to 3500 feet deep), but his disillusion with at least some aspects of the theory of glaciation is apparent, as he goes on to say that he "has been collecting data on the subject of glaciation in the Australian Alps for some years, but the subject is surrounded by many difficulties, and until more extensive examinations and researches . . . are made, it cannot be stated with certainty whether 'the golden washes of the latest period are in reality the products of glacial debris ground-sluiced by the ice-waters',* or the results of a more extensive pluviation".

David, who, with others, investigated the glacial features of the Kosciusko area and was interested in determining the extent of Pleistocene glaciation in Australia, stated (1908): "Mr. E. C. Andrews has recently explored the Bogong Range proper† and found that it is more in the nature of a high ridge unsuited to forming a gathering ground of an ice-sheet of considerable dimensions. The plateau of Fainter,‡ however, is of far greater extent and would probably have carried glaciers during the maximum glaciation of Mount Kosciusko."

Nothing more was heard of the idea of Pleistocene glaciation in Victoria until Hills (1940) stated that in Pleistocene times "glaciers were not formed on even the highest Victorian mountains". Crohn (1947) reports that he examined the hornblendic quartz porphyrite of Lendenfeld (hornblende porphyrite, Stirling) which these authors found on Mount Bogong. He identified the rock as hornblende diorite, and found abundant local outcrops from which the boulders could have been derived. He states that "the presence of the so-called facetted boulders is thought to be due to their well-developed tendency to break into angular blocks, parallel to closely spaced angular joint-planes". He also examined a large tract of mountainous country in the north-east of the State, and writes of it: "No traces of Recent or Late Tertiary glaciation were found anywhere in the area, and all evidence cited by previous authors was found to be readily explained by other means."

However, David (*Ed.* Browne, 1950) remarks that "it is extremely probable that at least the cirque-cutting stage of the Kosciusko area had its counterpart in some of the high country of north-east Victoria, which, however, may have been too limited in area to serve as a gathering ground during earlier glaciations".

In view of the elevation and extent of the Victorian Alps and of their proximity to the Kosciusko Plateau, we consider that it would be surprising to find that they had not been glaciated. Mounts Kosciusko and Bogong are less than eighty miles apart and, in the Bogong area and its environs, more than 200 square miles of country lies above the present-day winter snow-line (approximately 4500 feet). In certain places late-lying snow persists in snow-patches until late in summer, and sometimes throughout the year.

In the course of recent field work on the Bogong High Plains, Mt. Bogong and the Loch-Hotham-Feathertop area (Text-fig. 1), a variety of evidence was collected which leaves no doubt that at least these parts of the Victorian Alps were glaciated during

* Quotation from Griffiths.

† Mt. Bogong.

‡ Bogong High Plains.

the Pleistocene Period. The nature and significance of the evidence form the subject of this paper. Its full evaluation, leading to an exact knowledge of the extent, nature and number of glaciations, is not possible without considerably more detailed field work.

Physiography.

The area formed part of a peneplain uplifted during the Tertiary, reaching its final elevation probably in the late Pliocene. Within the area three broad physiographic units may be recognized. The largest and least dissected of these is the Bogong High Plains, which stand at a level of 5600 feet above sea-level, with individual peaks exceeding 6000 feet. The High Plains are separated from the steeper and much more dissected Loch-Hotham-Feathertop section by the valley of the West Kiewa River, and from the isolated steep Mount Bogong section by the East Kiewa and Big Rivers. The Kiewa and Big Rivers flow in steep-sided valleys which they have been enabled to cut as a result of rejuvenation at the time of the uplift.

Geology.

The area under discussion lies almost at the centre of the metamorphic belt of north-eastern Victoria. The most commonly occurring rock-types are gneiss, augen-gneiss, schists and granites. To the west, in the Loch-Hotham-Feathertop section, the area is bounded by Ordovician sediments, which are not so highly metamorphosed as the other rocks in the area. Extensive cappings of Older Basalt occur throughout the area, as for instance at Mounts Higginbotham and Loch, Mount Jim, and around the head of the Bundarrah River. Smaller areas of basalt are those of Basalt Hill and Mount Fainter. On the High Plains both Rocky Valley and Pretty Valley contain extensive areas of shallow alluvium (personal communication, Mr. F. Beavis).

Evidences of Glacial Action.

1. *General Remarks.*

The glacial geologist from those parts of the world which have been recently or severely glaciated will find in this rather subdued Victorian scenery none of the striking land forms with which he is familiar. In many parts of this area post-glacial headward erosion has been vigorous, and much moraine material has undoubtedly been removed and re-sorted by streams. In as yet undissected areas glacial forms have been masked to a certain extent by the rapidity with which the processes of post-glacial weathering and soil formation have sharpened some contours and smoothed others. The prevailing metamorphic and intrusive rocks of the area weather so readily that they could not be expected to retain for long evidence of the passage of ice over them, or of reshaping during transport. In addition, well-marked joint planes allow these rocks to split readily under weathering, so that the identification of undoubted faceted boulders and glacial pavements in the area is likely to be difficult and infrequent. Even the basalt, which is the most abundant hard rock of the area, cannot be relied upon to furnish much evidence of the passage of ice. It is columnar throughout the area, and the columns, whether *in situ* or broken off, tend to break under weathering into angular fragments. Also, it is thought that the passage of ice over an outcrop of basalt would produce a shattered, only approximately smooth surface rather than a polished striated one.

A striking feature of the whole area is the large number of boulders lying on the surface, and occurring as floaters at all depths in the soil. It is assumed that many of these boulders are relics of a widespread ground moraine. The blocks of hornblende-diorite which occur in curious positions on Mount Bogong may have arrived at their present positions as ground moraine, or simply by downhill creeping, a well-known phenomenon of boulder movement.

2. *Phenomena Associated with Valleys.*

The most convincing suite of related glacial features is that shown by Rocky Valley, a part of the High Plains which has suffered little recent dissection. The western half of the valley is occupied by alluvium above which project here and there irregular

masses of boulders. Rocky material first becomes prominent about the middle of the valley and from there, in an easterly direction towards Wallace's and Langford's Gaps, it increases in extent and depth so that the base of Basalt Hill is surrounded by a boulder field which extends over the divide and into the heads of Middle Creek (Pl. vii, fig. 1). Beyond this point the boulders are confined to the tops of spurs and are abundant in stream beds. It is concluded that the boulder field has been considerably reduced in size by stream action. The maximum depth of the boulder deposit is unknown, but it is exposed to a depth of twelve to fifteen feet in the Langford's Gap Cut constructed by the State Electricity Commission. The material exposed is unstratified, and consists of predominantly large rocks of irregular shape and size embedded in a matrix of finely divided material in which free minerals are abundant. Some, at least, of the finely divided material has been derived from the weathering of rocks *in situ*, as each of the buried rocks is surrounded by a shell of decomposed material. Favourable conditions for rapid weathering within the mass probably account for the comparative rarity of smaller rocks and stones.

As far as can be ascertained all the solid rocks on the surface, as well as those exposed in the cut, are of granodiorite. The orientation of those joint planes which are visible is extremely irregular. Here and there between the solid granodiorite boulders occur large masses of a soft decomposed rock which appears to have been originally schistose. Biotite is arranged in approximately parallel layers within each individual mass, but the banding of any one mass cannot be related to that of adjoining masses. This observed lack of regularity of arrangement suggests that the boulder field has not developed by weathering of the native rocks of the area, but is formed of transported material.

The present topography is one of low relief, and this condition has prevailed for a considerable period of geological time. This, taken in conjunction with that of the size of many of the boulders in this tumbled mass, makes it impossible to accept any suggestion that running water was the transporting agent. Very strong evidence that this boulder field is, as its appearance suggests, a recessional or ground moraine is the occurrence of boulders of granodiorite towards the top and on the slopes of Basalt Hill. One group of boulders occurs about half-way along the southern slope of the hill (point A, Text-fig. 1) just below a gap through which a set of wheel tracks passes. Another group has been reported near the top of the hill, still on the southern slope and some distance east of the main snow-pole line (personal communication, Mr. F. Beavis). In the tumbled mass of rocks below the persistent snow-patch at the south-eastern end of the hill there occur, mixed with the prevailing basalt, boulders of both quartz and granodiorite. We identify all these foreign boulders on Basalt Hill as glacial erratics.

The whole hill owes its shape to ice-action, the ice having passed over it from west to east. The western slope, which rises gently from Rocky Valley, is identified as the scour or stoss slope. The eastern face, which is abrupt, is the plucked or lee slope. The same association of scour and pluck slopes is shown on a smaller scale by the small humps of basalt which project above the generally smooth contours of the southern slopes of the hill. Although Basalt Hill appears to have been overridden by ice, it also seems to have had the effect of parting the sheet or stream of ice, and diverting strong flows over the softer rocks to north and south. This allowed the gouging out of Langford's and Wallace's Gaps. The two valleys so formed (or deepened) were later partly filled with moraine material.

Other major glacial features occur in the Mt. McKay Branch of Rocky Valley, some four to six miles west-north-west of Basalt Hill. The present stream meanders in alluvium and peat in the flat bottom of a large and deep valley, many features of which indicate that it was formerly occupied by ice. At B (Text-fig. 1) the valley is straight and forms a U-shaped trough. Here the spurs are truncated, and the numerous lateral valleys entering from the south are hanging. Upstream at B the main valley broadens to form a more or less semi-circular steep-sided amphitheatre, in the floor of which there are indications of overdeepening. The wide valley-head appears to have been


Bogong 3300a Hill
Mt. Little Bogong 5466
Mt. Bogong 6509
Mt. Bogong Central 6435
Mt BEAUTY TOWNSHIP
Kiewa River
Bogong Ck.
West Kiewa
FAULT
EASTON'S
Greene's Ck.
Big Hill 4545
Mt. Arthur 5483
Mt. Lt. Arthur 5042
Becker's Ck.
Camp Ck.
Big River
Diamond Lookout Spur
Dungey's Ck.
Dungey's Spur
Reef Ck.
West Quartz Spur
Ropers Spur
Battye Hut
BOGONG VILLAGE
Bald Hill 5132
Spion Kopje Ck.
Spion Kopje
Little Spion Kopje 5638
6032
Rocky Branch
Dyramid Hill
Kiewa River
Mt. Fainter Nth. 6028
Mt. Fainter Sth. 6157
Valley
6181 Nelse Nth.
Heathy Spur
6175 Mt. Nelse
Johnston's Hut
Ropers Lookout
Watchbed Ck.
Fitzgerald's Hut
Langfords Gap
Basalt Hill
Wallace's Gap
Wallace's Hut
SEC Cottage
Mt. Kay Creek
Mt. McKay 6045
Mt. Feathertop 6306
Niggerhead 6058
Niggerhead Ck.
Tawonga Hut
Pretty Valley
Scout Hut Branch
Middle Ck
Blairs Hut
Mt. Jim 5916
Jim Creek
5653 Bundarrah
Mt. Cope 6024
Pendergast Ck.
Dingeldein River
Diapina Hut
Coburg Ck.
Mt. Loch 6152
Young's Hut
Bundarrah River
Mt. Hotham 6100
Sandy Ck.
Mt. Higginbotham
Little Mt. Higginbotham
Mt. Blowhard
Coburg Ck.
MAP OF BOGONG HIGH PLAINS AREA
Ridges
Roads
0 1 2 3 4
SCALE OF MILES

formed as the result of extensive cirque-cutting, the snow being drawn from the flatter country which lies above. The tributary streams entering from this flatter country hang high above the main valley, and show a number of characteristics which indicate the influence of ice on their development. They are straight, have stepped profiles, and head at broad gaps of the type which Browne (1952) identifies in the Kosciusko area as ice-divides or cols. In cross-section these valleys have the form of shallow, smooth arcs (Pl. vii, fig. 2). In those in which the course is such that present-day snow melts earlier from one side than from the other, the rock of the protected south- or east-facing slopes is comparatively smooth. There are few loose boulders or stones. On the opposite slopes, which are exposed to severe frost action by the early melting of snow, free boulders with roughened surfaces are common, and the terrain is rough and broken. We suggest that the smoothed contours of the sheltered slopes are little-altered relics of glaciation. On the exposed slopes severe sub-aerial weathering has destroyed the smoothness of contour imposed by the flow of ice down these valleys.

Of the other glacial features of Rocky Valley there is little more to be said. At C there is a well-marked bench of rocks. This may have originally been a lateral moraine, but there is some evidence that the material has been re-sorted. On this northern side of the valley the lower slopes carry very numerous boulders of assorted sizes. These may well represent lateral or ground moraine. Other features of the valley which suggest glaciation are the rounded and smooth small hills which rise from the floor of the valley.

The drainage pattern of Rocky Valley is unusual. The Mt. McKay Branch flows almost due east, the Watchbed Branch approximately south-west. The two join in mixed alluvium and moraine to form the Rocky Valley Branch of the East Kiewa. This stream pursues a course approximately N.N.E. over its kink-point into a very immature valley. We suggest that the following sequence of events is responsible for the formation of this drainage pattern.

The Watchbed Creek and Mt. McKay Creek once formed part of the headwater system of Middle Creek. Their valleys were occupied by glaciers and their form directed the flow of ice past Basalt Hill into the head of Middle Creek. With the retreat of the ice, moraine dumped in Langford's and Wallace's Gaps dammed the streams, so that the main area of Rocky Valley was occupied by a lake, in which the greater part of the alluvium now present in the valley was deposited. What has not been determined is whether the lake-level was high enough to spill water over into the East Kiewa, or whether the lake was drained simply by the headward erosion of that stream, which was given tremendous cutting power by the uplift of the whole area and the development of a fault line a few miles to the north.

In other parts of the High Plains there are examples of large valleys which appear to have been occupied and modified by ice. The most notable of these is the head of Redbank Creek (Bundarrah River), which is broad and cirque-like in its headwater region under Mount Jim, and then pursues a straight course through a U-shaped valley for approximately one mile. There are no definite moraines associated with this valley, but the abundance of rock in its floor suggests that any moraine material originally present has been re-sorted and much of it transported by stream action.

Jim Stream, one of the main tributaries of Pretty Valley Creek, also shows many glacial features. A small boulder field is present in its lower reaches. This may represent a re-distributed moraine.

The three large valleys mentioned all head between 5800 and 6000 feet. Other valleys at about the same elevation have been much modified by recent dissection, so that it is difficult to determine the extent to which they have been glaciated. At slightly lower elevations (5400 to 5800 feet), on the less dissected edges of the High Plains, particularly in the section between Young's Hut and Basalt Hill, there is a series of smaller valleys which also show distinct evidence of glaciation. The positions of known examples are marked on the map (Text-fig. 1, numbers 1 to 5). All the valleys marked originate in cirque-like heads which, in some cases, are expanded so that they are

wider than the valleys. For distances as great as half a mile from their heads these valleys are U-shaped and straight, and the streams they contain flow on flat grades. Further downstream the grade steepens sharply and the spurs overlap. One almost constant feature of these small valleys is the presence, at a varying distance from the head, of a pair of barriers of loose rocks. In the Scout Hut Branch of Middle Creek the rock barriers are about 50 yards apart. The lower one is about ten feet, and the upper one about five feet high. In valleys 3 and 4 the barriers are higher than this, and at a greater distance from the head of the stream. Mossbeds are commonly situated behind the rock barriers. In valley 4 the stream is entrenching itself between the lower mass of rocks and the smoothed rock surface the barrier rests on.

The large, very level mossbed at D (Text-fig. 1) may owe its origin and present drainage to ice-action. The area appears to have been scooped out into a broad, saucer-shaped hollow by ice moving in an easterly direction from the slopes of Mount Cope. At the eastern end, where appearances suggest that the stream originally descended the slope to join the Bundarrah, the course has been blocked by a mass of boulders. The present drainage is to the west, and the basin itself has filled with peat.

The glaciated valleys so far described are on flat to moderate grades. On mountains such as Bogong, Fainter and Loch, where dissection was well advanced at the time of glaciation, much steeper valleys show evidence of ice-action. These valleys head in large or small cirque-like hollows, below which their courses are U-shaped, straight and, in contrast to those of flatter country, narrow and deep. The valley floors are almost clear of stones and rocks, and it appears that present-day creep of snow tends to maintain this condition. The valleys of this type show wide variation. At one extreme of development there are those which consist of little more than a corrie marking the site of a former cirque (Pl. viii, fig. 1); at the other extreme, narrow U-shaped valleys run down as chutes from some of the highest peaks, as on the south-western sides of Mount Fainter and Spion Kopje (Pl. viii, fig. 2). Many of these valleys have been modified by stream action. It should be pointed out here that straight courses and steep profiles are highly characteristic of youthful streams, of which there are large numbers in the area. We have distinguished between those which show glacial features and those which do not.

The features so far described provide evidence that glaciation has played a part in shaping the High Plains area. In addition, the shapes of the mountains and hills appear to be due in some measure to the action of ice. This aspect of the problem will be dealt with in a later section. Other features are doubtfully of glacial origin. The most prominent of these are what are known locally as "ledges". They are flat or gently sloping terraces which lie just below the level of the broad main tops, giving the upper slopes a stepped or benched profile. They are common in the least dissected parts of the area, and are well developed in the headwater regions of the Cobungra and Bundarrah Rivers and of Middle Creek. Cotton (1942) states that although benched hillsides are common in glaciated country, the way in which they are formed is unknown. It is possible, but not certain, that in this area they were formed on the sites of large accumulations of permanent snow.

3. *Phenomena Associated with the Older Basalt.*

The basalt of the area is columnar. Once it is exposed to physical weathering it tends to break into large angular blocks. On the very exposed upper slopes and plains of basalt, orientated accumulations of these blocks occur. On gently sloping or level ground large rock-rings or stone-polygons are common. On country of greater slope the rocks are arranged to form stone-stripes. These features have been observed in the following places: between the head of the Bundarrah River and Mount Jim, Basalt Hill, the head of Niggerhead Creek and Mount Loch.

Von Engelen (1942) states that the "requisite conditions for these developments are permanently frozen ground at depth, subject to deep thawing and complete saturation of the upper part in the warm season and by day, with repeated partial refreezings at night". Cotton (1942) regards these features as periglacial. In the

northern hemisphere they are recognized as characteristic of arctic, arctic-alpine and, to a lesser extent, alpine conditions (Lindquist, 1948; Costin, 1955). As far as is known, the conditions necessary for the formation of polygonal ground and stone-stripes do not obtain on the High Plains under the present climatic régime. Their presence reflects much more severe climatic conditions in the past. This is supported by the observation that as they occur now they are invariably associated with well-developed vegetation (Pl. vii, fig. 3).

Where basalt occurs as a capping to long slopes, the blocks dislodged by weathering from the steep face of the basalt mantle the upper slopes. In steep country the blocks tend locally to become concentrated in "boulder runs", which continue downwards for hundreds of feet. "Boulder runs" are common in the valleys of the Cobungra and Bundarrah Rivers. It is known that these streams of rock are still in motion.* It seems, therefore, that present-day conditions contribute to their persistence. They may have been more extensive and more rapid in movement in the past. This is suggested by the observation that most boulder runs have wide marginal areas hidden by shrubs. These parts appear to be more stable than the narrow central portions, which are free of vegetation.

In those places where basalt occurs capping country of lesser slope (as, for instance, around the head of the Bundarrah River at Basalt Hill), accumulations of boulders are commonly heaped at the foot of cirque-like hollows in the steepened eastern and southern faces of the basalt. It is common to find that these boulder heaps thin out downhill into broad sheets of loose rock, which appear to have much in common with the "ploughed fields" (of boulders) of Tasmania. It is not known to what extent present-day nivation is responsible for the formation and maintenance of these masses of rock, nor whether they are stable or in motion. The growth of shrubs over considerable areas of boulder heaps may indicate that the snowdrifts with which they are associated were much more extensive in the past than they are now.

Discussion.

The character and distribution of the glacial features which have been preserved indicate that their formation was due to the action of a névé-field rather than of an ice-cap. The glacial features are of a number of kinds and each kind is characteristic of the slope of the country on which it occurs. It seems, therefore, that at the time of glaciation the topography was much the same as it is today.

Mount Feathertop and its associated ridge, the Razorback, are steep-sided and lack summit plateaux on which great depths of snow could accumulate. They appear to have been sharpened by the movement of ice on their slopes and by severe nivation (Pl. viii, fig. 3). The upper part of Staircase Spur (Mount Bogong) shows similar features in an extreme form. In this type of country cirque-like hollows occur, but they are shallow and not well-developed.

The effect of snow on the ground on which it lies depends on the depth accumulated. Under present-day conditions snow is blown from the windward slopes and accumulates on the lee slopes. A similar redistribution is likely to have occurred with the heavier snowfalls of the glacial period. On gently undulating areas snow probably accumulated on southern and eastern slopes beyond the critical depth at which névé is transformed into ice, so that cirque formation occurred. This resulted in the plucking and steepening of the upper parts and the hollowing-out of the lower parts of these slopes. On the other hand, on the northern and western slopes, which carried comparatively shallow névé, slow downhill movement of ice had the effect of smoothing the contours and of transporting loose material as ground moraine. These differences in the behaviour of snow on slopes of opposed aspect resulted in asymmetry of ridges.† In later times, during which periglacial conditions existed, weathering forces operated to maintain this asymmetry. Ice-plucking continued on sheltered slopes at the heads of permanent snow drifts (Pl. vii, fig. 4). Although frost action was probably severe on exposed

* Personal communication, Mr. F. Beavis.

† Stirling (1882) mentions that throughout the area the southern slopes are steeper than the northern slopes, but does not ascribe this to the effects of glaciation.

slopes, it was more or less uniform over these slopes and tended towards the maintenance of their general smoothness. At this time stone-stripes and stone-polygons developed. Today, moderately severe frost action continues on the exposed slopes from which snow melts early, but on most of the sheltered slopes late-lying snow has a protective effect. The presence of deep soils under snow patches indicates that ice-plucking is no longer going on and has not gone on for some time. It only occurs today in rare instances at very high elevations.

During the glacial period the downhill movement of ice on both exposed and sheltered slopes contributed to its accumulation in valleys. Where conditions were suitable, valley glaciers of considerable size developed and were fed by numerous smaller tributary streams of ice. However, many of the smaller valley glaciers were independent. Those which discharged onto flatter country left irregular heaps of rock, either in their own valleys or beyond them, to mark their termination. Others discharged onto steep country and their valleys contain only a small amount of morainic material. The valleys which mark the former ice-falls of small valley glaciers have the appearance of chutes. They have been straightened and scoured by rapidly moving ice.

The relationship of the most prominent glacial features to one another is fairly clear, but it is not always obvious how the smaller features are related either to one another or to the major features. The sequence of moraines in the Scout Hut branch of Middle Creek indicates that there was considerable fluctuation in the length of the glacier which occupied it. There is evidence that a similar fluctuation occurred in other small valleys. It is possible that small glaciers were formed in such valleys on a number of occasions. On the other hand, the moraines may indicate stages in the retreat of a single glacier. Much more work is necessary before this question can be cleared up.

Another thing which is obscure is the chronological relationship between the glaciation of this area and that of the Kosciusko Plateau. Browne (1952) considers that the glacial features of the Kosciusko Plateau can be assigned to three periods. In the first, ice-sheets moving from west to east imposed on the surface rocks their rounded and smoothed outlines and were responsible for converting most of the mountains into great *roches moutonnées*. The wide flat cols and saddles which are of common occurrence throughout the area are thought to have had their origin at this time. The second period involved the formation of valley glaciers and the third was a time of cirque-cutting. The High Plains area is very similar in general appearance and physiography to the Kosciusko Plateau. Wide flat saddles in which the water-parting is indistinct are very common, and most of the mountain peaks have a form similar to that of *roches moutonnées*. There is evidence of the former existence of valley glaciers and cirques. A superficial examination of the area might suggest that events have followed a course similar to that postulated for the Kosciusko Plateau. Nevertheless, it appears most improbable that they did so.

The *roche moutonnée* form is shown by peaks and hills which are isolated from the main massif, as well as by those arising from the plateaux. The indications are that it was imposed by weathering factors common to prominences over the whole area, rather than by the regional movement of ice, which could have affected only part of the area. The observations which are critical in disposing of the possibility that the area was subject to glaciation of the ice-cap type are those which relate to Spion Kopje and Mount Fainter. These are long narrow spurs projecting from the northern edge of the High Plains. The top of Spion Kopje consists of an overlapping series of smooth and asymmetrical ridges. On Mount Fainter the three small humps which form the summits of the narrow ridge have gentle western and steep eastern faces. Unless, at the time of glaciation, these spurs and others like them were still undissected from the original peneplain of which they are remnants, they could not have been affected by ice-sheets moving across them. They stand too high above the surrounding country and their sides are too steep to have allowed them to be affected by ice accumulated elsewhere.

The assumption that at least the outlines of the present topography date from the Early Pleistocene is based on the following argument. The chronology of Tertiary and

subsequent events in this part of Australia is uncertain, but it is thought that the movements which gave rise to the Eastern Highlands began in the Early Tertiary. The final uplift, which was accompanied by faulting, is thought to have taken place in the Late Pliocene or Early Pleistocene. Spion Kopje and Mount Fainter, Mount Bogong and Feathertop lie close to the scarp marking Easton's Fault, so that in the pluvial conditions continuing from the Pliocene into the Pleistocene headward erosion of the rejuvenated Kiewa River would have quickly isolated them from adjacent country. The great depth and width of the valley of the Kiewa suggest that its age is considerable. Confirmatory evidence comes from the observation that the Bogong and Cobungra Gaps are very deeply incised.

It is impossible on the present evidence to date the glaciation of the High Plains area accurately. All that is clear is that it occurred after the final uplift of the area. The fact that all the moraines so far observed are much weathered, while both weathered and fresh moraines are present in the Kosciusko region, suggests that glaciation in Victoria was contemporaneous with an early stage of the Kosciusko glaciation. The later phases of the Kosciusko glaciation are possibly not represented in the Victorian Alps because of their lower altitude.

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EXPLANATION OF PLATES VII-VIII.

Plate vii.

Fig. 1.—Boulder Field, Langford's Gap.
Fig. 2.—Broadly U-shaped valley below Young's Hut, near head of the Bundarrah River.
Fig. 3.—Large stone polygons, on basalt, near Mt. Jim.
Fig. 4.—Basalt Hill, showing effect of continued ice-plucking on site of snow drift.

Plate viii.

Fig. 1.—Cirque-like hollow at the head of the eastern arm of the Diamantina River, Loch-Hotham Spur.
Fig. 2.—Steep, U-shaped valley on south-western slope of the North Fainter.
Fig. 3.—Mt. Feathertop, showing snow- and ice-sculptured features.

ROBERT BROWN'S AUSTRALIAN COLLECTING LOCALITIES.

By Nancy T. Burbidge, Division of Plant Industry, C.S.I.R.O., Canberra.

(*Communicated by Miss Joyce W. Vickery.*)

[Read 26th October, 1955.]

Synopsis.

The type localities for the species of Australian plants described by Robert Brown in his "Prodromus Florae Novae Hollandiae" have never been critically considered. In many cases, since Brown did not quote actual specimens, it will be necessary to select lectotypes and for the proper determination of these the identity of certain code or field names for localities is required. These code names are associated with plant dscriptions left in manuscript, and from a study of the latter, in association with certain original charts prepared by Matthew Flinders, it has been possible to correlate the field names with modern localities.

Knowledge of the type locality of most of Brown's species of Australian plants has been dependent, in many cases, on the bare facts given on labels prepared after Brown's death and attached to distributed duplicates. In his "Prodromus Florae Novae Hollandiae" and other publications on Australian plants Brown gave the locality of his species in only the most general geographic terms. Furthermore, he described them very briefly. Consequently his terse descriptions and inadequate locality data are barely sufficient for identification.

In the "Prodromus" the portions of Australia from which Brown obtained specimens were denoted by the letters (I), (M), (T), (O), and (D), the only exception being the material collected by Banks and Solander on Cook's First Voyage. This was identified by "B" in the relevant parts of the text. Since these letters referred to wide tracts they are quite useless for the determination of type localities. The letter (M), for example, covers plants collected between Cape Leeuwin in Western Australia and Wilson's Promontory in Victoria, an area which shows considerable variation floristically as well as geographically. Furthermore, the information required is not readily obtainable from the distributed specimens.

During his lifetime Brown was never particularly generous with his collections. No specimens were distributed and they could only be consulted after his personal permission had been obtained for a botanist to visit the British Museum during certain limited visitors' hours. In his will he appointed J. J. Bennett, who was his successor at the Museum, as his executor, and it fell to Bennett to arrange for the distribution of duplicates, a task which was not completed until after Bennett's death in 1876. It is these duplicates which are usually quoted as "types", and it is from the meagre details recorded on their labels that information as to locality has generally been derived.

Since Brown did not number his specimens consecutively during the voyage in the *Investigator* with Matthew Flinders, or during the subsequent periods in New South Wales and Tasmania, Bennett added numbers to all the material, and a full list of these is in the botanical library of the British Museum (Natural History) in South Kensington. Unfortunately these numbers were related to the names of species in the "Prodromus" rather than to individual specimens. Consequently there are cases in which the same number has been applied to specimens from different localities and it will be necessary to select lectotypes in such instances. For example, in the Herbarium of the Royal Botanic Gardens, Kew, there are two Brown specimens of *Atriplex semibaccata* under the same Bennett number, though one is from "Port Jackson" and the other from a locality on the Queensland coast.

Apart from the Bennett series of numbers some of the plant descriptions left in manuscript bear numbers inserted by Brown at the time of writing. These are usually written as "No. 54 spec." or "No. 17 sp.", and it is believed that they represent items in series from particular localities. The matter has not yet been satisfactorily established, but the fact that a note by Brown, attached to the sheet of *Orites diversifolia* in the type collection at the British Museum, states "desc. in Mscr. Fluv. Derwent No. 11" appears to confirm the assumption. These numbers do not appear to have been quoted in any publication nor have they been used, up to the present, to assist in the correlation of available information. The manuscript numbers used by Brown are not found on all his manuscript descriptions and it is possible that they were not quoted by Bennett because of their incomplete coverage of the material. Fortunately the descriptions also bear locality data, and it is this last which is the basic reason for preparing this paper.

During his period as naturalist with Matthew Flinders, in the *Investigator*, Brown found it necessary to employ code names for localities not previously known on maps. These were evidently prepared either by Flinders in the compilation of his survey notes or by Brown and Flinders in collaboration. There seems to have been no previous attempt to correlate all these code names with those on modern maps or even with the places in the charts published by Flinders and referred to in his text. Such a correlation is now possible because of a study of the plant descriptions left in manuscript by Brown and also because Flinders' "original" charts have been located in the Mapping Division of the Admiralty. The former give names in association with code localities and collecting dates, while the latter permit a proper check with recent maps. Copies of the original charts have been obtained and are now in the herbarium of the Division of Plant Industry, C.S.I.R.O., Canberra.

The study of the plant descriptions and the search for the charts arose as a result of a resolution passed by the Australian and New Zealand Association for the Advancement of Science in 1949. This requested the Australian Government to obtain microfilm copies of the manuscripts left to the British Museum by Robert Brown. These manuscripts are now held in the botanical library of the Natural History Museum in South Kensington, and the microfilm, prepared with the kind co-operation of the Trustees of the British Museum, is available in Australia. During 1953 and 1954 the author, while in London, prepared an index to the largest series of the papers, i.e., the plant descriptions, many of the Australian items among them having been written while on board the *Investigator*.

The periods during which code locality names were used are those during the voyage from King George's Sound to Port Jackson and from Port Jackson to Arnhem Bay. These are denoted, in the "Prodromus", by the letters (M) and (T) respectively.

The *Investigator* arrived at King George's Sound, frequently referred to by Brown as "King George III. Sound", early in December, 1801, and remained there until the end of the first week of January, 1802. The survey then proceeded along the south coast of Western Australia and South Australia to Encounter Bay, whose name commemorates the meeting with the French expedition under Baudin. The French having already surveyed the coast which the *Investigator* was now passing, Flinders proceeded direct to King Island, which Baudin's party had missed. From there he made for Westernport, but entered Port Phillip instead. After spending a few days there he sailed for Port Jackson, which was reached on May 9, 1802.

Port Jackson was left late in July and Brown's collecting from the ship recommenced at Sandy Cape on July 31st. Work continued north to the Cumberland Islands, where, on October 18th, the *Investigator* parted company with the *Lady Nelson*, which had accompanied her from Port Jackson. From here they went north to Murrays' Islands in Torres Strait and thence to Prince of Wales Islands off the Cape York Peninsula, where collecting recommenced, there having been a break from the time at the Cumberland Islands. In the Gulf of Carpentaria more than four months (early November, 1802, to early March, 1803) were spent surveying the coasts around to

Arnhem Bay. While in the Gulf it was found that the timbers of the ship were in a dangerous state of disrepair, and from Arnhem Bay, partly owing to this and partly to the advancing season of the year, Flinders sailed for Timor. They returned to Port Jackson by circumnavigating the continent, the only stop being for a brief call at Goose Island Bay on the south coast of Western Australia. This is recorded by Brown's notes on a few specimens.

Flinders' misfortunes from this time have been dealt with elsewhere and, since they do not directly involve Brown's collecting expeditions, need not be discussed here.

With this short account of the route followed, the results of correlating the code names with localities on modern maps can now be given. They are as follows:

Western Australia.

Bay I. (or Bay 1.)	Lucky Bay, E. of Esperance Bay.
Bay II. (or Bay 2.)	Goose Island Bay, off C. Arid.

South Australia.

Bay III. (not to be confused with Bay No. 3 of March, 1803)	Fowler's Bay.
Bay IV.	Petrel Bay, Isle St. Francis.
Anchorage V.	Off Franklin Isles.
Anchorage VI.	Isles of St. Peter, Denial Bay.
Anchorage VII.	Waldegrave Island, after which a visit was paid to Flinders Island in the Investigator Group.
Anchorage VIII.	Off Thistle Island.
Bay IX.	Memory Cove.
Bay X., 1st Anchorage	Port Lincoln, west side of Surfleet Point off Stamford Hill.
Bay X., 2nd Anchorage	Port Lincoln, S.W. corner.
Bay X., 3rd Anchorage	Port Lincoln, cove west of Cape Donington.
Anchorage XI.	Off Kirkby Island.
Inlet XII. (or Bay XII)	Spencer's Gulf (presumably near the head, since Brown walked to Mt. Brown).
Anchorage XIII.	Kangaroo Head, west end of Nepean Bay, Kangaroo Island.
Bay XIV. (or Inlet XIV.)	St. Vincent's Gulf (Flinders and Brown visited the head of the gulf).

Victoria.

Anchorage XV.	Off King Island in the western entrance to Bass Strait.
Bay XVI. (or Port XVI.)	Port Phillip.

Queensland.

Port I.	Between Curtis and Facing Islands.
Port II. (or Port 2.)	Port Clinton.
Shoal Bay, Passage III.	Strait south of Townshend Island, Shoalwater Bay.
Port III. (or Port 3.)	As for Passage III.

Cumberland Islands.

"Islands 1 and 2 of chart"	Island 1 not identified. Brown mentions only one landing; this seems to have been on Calder Island, marked 1_2 on chart.
Island d.; Island α	Flinders mentions landing at one of the Murray Islands and also at Halfway Island (Octr. 30th, 1802), but it is not clear which received which code name.
Prince of Wales, Island e.	Good's Island, named after the gardener on the *Investigator*, though many maps show it corrupted to Goode Island.

Gulf of Carpentaria.

Note: Throughout the survey of the Gulf, points on the mainland and on some of the islands were identified by capital letters. Islands were noted under small letters.

Series of Survey Points.

A. Duythen Point.
B. Pera Head.
C. Not identified under special name, no landing made.
D. Cape Keerweer.
E. See C.
F. See C.
G. Gore Point.
H. S.E. point of Sweer's Island.
I. Point on Sydney Island, E. of Mornington Is.
I_1. Point on south coast of Mornington Island.
K. Cape Van Diemen.
K_2. Point to W.S.W. of K.
K_3. Northernmost point of Mornington Island.
L. Point on west coast of Mornington Island.
L_2. Point on west coast of Mornington Island to N.E. of above.
M. Mouth of Calvert River.
O. Sandy Head, N.W. of mouth of Robinson River and south of Vanderlin Island in Sir Edward Pellew Group.
P. Cape Vanderlin.
Q. Mt. Young, mainland S. of Maria Island. On one of the original charts this is marked as Cape Maria, which, in the published series, is given as the northern point of Maria Island.
R. Cape Barrow.
R_1. Point in the S.W. angle of Bennett Bay, southern part of Blue Mud Bay, between Lela and Harris Creeks.
S. Point Blane.
T. Cape Shield.
T_1. Point Arrowsmith.
U. Cape Grey.
U_1. Mt. Caledon.
U_2. Point Alexander.
V. Mt. Alexander.
W. Hill behind Cape Arnhem.
W_1. Mt. Dundas.
W_2. Mt. Saunders.
X_1. Southern point of inlet to south of C. Wilberforce.
X_2. Point S.W.W. of Cape Wilberforce (Mt. Bonner).
X_3 to X_7. Points along coast to Cape Newbald.
Y_1, Y_2. Points on coast of Arnhem Bay to E. of Cape Newbald.
Y_3. Cape in S.W. angle of Arnhem Bay.

Island Series.

a. Sweer's Island.
b. Bentinck Island.
c. Allen Island.
d. Mornington Island.
d_1. Forsyth Island.
e. Pisonia Island.
e_1. Island off N.E. cape of Mornington Island.
f. One of Bountiful Islands.
f_1. One of Bountiful Islands.
g. Vanderlin's Island.
h. North Island, Sir Edward Pellew Group.
hh. Centre Island, Sir Edward Pellew Group.
i. South West Island, Sir Edward Pellew Group.
k. West Island, Sir Edward Pellew Group.
l. Maria Island.
m. Groote Eylandt.
m_1
to
m_8. Islets off S.E. corner of Groote Eylandt.
n. Bickerton Island.
o. One of the North East Islands.
o_1. One of the North East Islands (Hawk Island).
p. Winchelsea Island.
q. Low Sandy Islet, N.W. of Winchelsea Island.
r. Burney Island.
r_1. Islet off east coast of Burney Is., towards Wedge Is.
s. Morgan's Island.
s_1. Woodah Island.
s_2. Nicol Island.
t_1. Fowler Island (N.W. part of Blue Mud Bay).
u. Gooninah Island (to E.N.E. of Cape Shield).
v. Bridgeland Island } Entrance to
v_1. Dudley Island } Caledon
v_2. McNamara Island } Bay.
v_6. Islet off Mt. Alexander.
v_7. Islet off Mt. Alexander.
w. Bremer Island.
w_1
to
w_5. Islets surrounding Bremer Island.
w_3. E. Woody Island.
w_4. W. Woody Island.
x
to
x_2. Bromby Islands.
y. Wigram Island.
y_1. Cotton's Island.
y_2 Pibassoo's Island.
y_3. Astell's Island.
y_4. Islet to N. of Astell's Island.
z. Inglis Island.
z_1
to
z_3. Islets to N. of Inglis Island.
z_4. Bosanquet's Island.
α. Mallinson's Island. ⎫
α1. Everett Island. ⎪
α2. Hardy Island. ⎪ Islands in
α3. Island to N. of ⎪ entrance to
Everett Is. ⎪ Arnhem Bay.
β. Probable Island. ⎪
β1. Gwakura Island. ⎭

Arnhem South Bay: This name, used by Brown (spelt "Arnheim" in the manuscripts) and also by Bentham in the Flora Australiensis, refers to Caledon Bay of the published charts.

Arnhem North Bay: This name also used by Brown, followed by Bentham, refers to Melville Bay of the published charts.

Bay No. 3: Arnhem Bay of the charts and modern maps.

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THE GENERA *CAMPYLOCHIRUS* TROUESSART AND *AUSTROCHIRUS* WOMERSLEY IN AUSTRALIA (ACARINA, LISTROPHORIDAE).

By Robert Domrow, Queensland Institute of Medical Research, Brisbane.

(Eight Text-figures.)

[Read 26th October, 1955.]

Synopsis.

Campylochirus chelopus Trouessart, 1893, the genotype of *Campylochirus* Trouessart, 1893, is redescribed and figured from the type host and locality. A new species of *Austrochirus* Womersley, now regarded as distinct from *Campylochirus*, is described from a water-rat from North Queensland. A key to the three known species of the genus is given.

Recently I received from Mr. H. Womersley several slides of listrophorid fur-mites from a ring-tail possum from Tasmania, containing adults of both sexes and a single pre-female nymph of a species of the subfamily Atopomelinae. The only species of ring-tail possum in Tasmania is *Pseudocheirus convolutor* Oken (= *Phalangista cooki* Desmarest).

Trouessart (1893) described *Campylochirus chelopus* (the genotype of *Campylochirus* Trouessart, 1893) from specimens from the same host and locality, his original and subsequent (1917) descriptions being quite brief and without illustrations. The species has not been recognized since, and the original specimens are not in the Trouessart collection (André, *in litt.*). The male and nymph of the new material agree with Trouessart's description in essentials. I believe that they are his species, that his original material lacked adult females, and that he mistook pre-female nymphs for adults.

The female of the new material has three distinct dorsal shields, while the nymph has only a single antero-dorsal shield. To ascertain Trouessart's conception of his genus *Campylochirus* I have examined adults of three undescribed Australian species which Trouessart himself attributed to this genus. In these the adults of both sexes have a single antero-dorsal shield like the nymph of the new material, and therefore do not conform to the genotype. If Trouessart's other two described species, *C. adherens* and *C. latus* (which are not Australian and not in the Trouessart collection) also conform as adults to his criteria, the genotype would be the only species left in *Campylochirus*. The three undescribed species conform to *Austrochirus* Womersley, 1943, the adults of which have a single antero-dorsal shield. In an earlier paper (Domrow, 1955, which contains all the references relevant to this paper) I wrongly regarded *Austrochirus* as equal to *Campylochirus* on the assumption that the latter was based on adult specimens.

A detailed description and figures of *C. chelopus* are given below, together with a description of a new species of *Austrochirus* from a water-rat from North Queensland.

Campylochirus chelopus Trouessart, 1893.

Female.

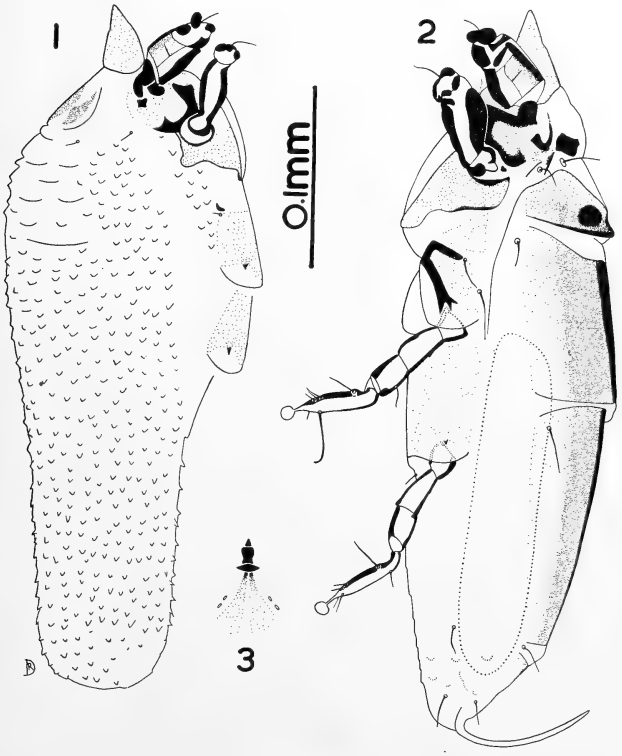
A slender, heavily sclerotized form, with capitulum completely uncovered. Dorsum with three sclerotized shields, whose lateral margins are very indistinct. There is a suggestion of a fourth shield near the end of the opisthosoma. Four setae with large bases in front of first dorsal shield, and one near the antero-lateral corners of each of the others. End of opisthosoma with about six setae and a few small, indistinct scale-like markings, and with an elongate process 80 to 88μ long.

Legs I and II typical of subfamily, both heavily sclerotized, and rather flat, tarsus II at least with caruncle in ventral view. Coxae III and IV separate and sclerotized, forming a flap over the basal movable segment of legs III and IV. Articulatory process for leg III much more heavily sclerotized than that for leg IV. Two setae above, and a

triangular sclerotized zone in front of coxae III. Legs III and IV simple. Penultimate segment of leg III with a single seta, tarsus III with strong apical seta. A pair of setae on a small process between legs IV.

Genitalia placed between legs III in weakly sclerotized cuticle, with three anterior sclerotized bodies, and with two posterior sclerotized zones fading and spreading into the general cuticle, and flanked by two pairs of very small suckers. Egg single, elongate, with almost parallel sides, 190μ long, 38 to 42μ wide.

Average length, excluding terminal process, 400μ, range 373 to 436μ.

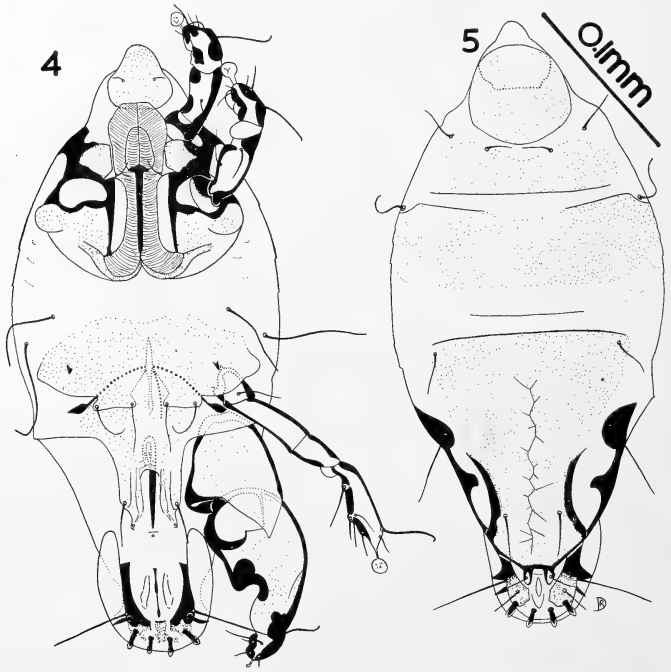


Text-figs. 1-3.
Campylochirus chelopus Trt. 1, Nymph; 2, female; 3, female genitalia.

Male.

A rather stouter form. Capitulum slightly more than half covered dorsally. Dorsum with three indistinct shields. Four setae along anterior margin of first shield, one at each antero-lateral corner of second. Third dorsal shield with seta in each antero-lateral corner, and two near postero-lateral margins, which are heavily sclerotized, and produced posteriorly into two small projecting processes, each bearing a short seta; with a zig-zag marking medially. At a somewhat lower level is a marginally transparent, flap-like extension around the end of the body, with two basal horns and six lobed processes. A pair of long setae are inserted ventrally near the horns. Anus longitudinal, and placed ventrally on this terminal lobe.

Legs I and II heavily sclerotized and with distinct caruncles. Clasping organ with a pair of setae between coxae I and II; with a W-shaped sclerotization posteriorly, and sternum heavily sclerotized. Coxal areas III and IV sclerotized and meeting medially, forming a flap over the basal movable segment of the legs. Coxal areas III with four long setae near antero-lateral corners and four on small lobes on posterior margins; with articulatory process for leg III small. Coxal areas IV produced postero-medially, flanking the dark, curved, blade-like penis, and with two setae. Articulatory processes for legs IV larger, and joined by a heavily sclerotized arc which passes forward between



Text-figs. 4, 5.
Campylochirus chelopus Trt. 4, Male, ventral; 5, male, dorsal.

legs III and is covered by coxal areas III. Leg III simple, basal movable segment with a single seta, tarsus III with strong apical seta. Leg IV greatly swollen and heavily sclerotized, basal segment without seta. Caruncle IV much reduced.

Length 350 to 358μ.

Nymph.

Capitulum, legs, and ventral sclerotization as in female, except that coxae III are not as heavily sclerotized. Anterior dorsum with small, apparently 3-lobed shield. Rest of body covered with small papillae which are somewhat larger near the dorsal shield, and rather pointed posteriorly. Without any terminal process or lobe. I believe this nymph to be pre-female, and that the form described by Trouessart as an adult female was really a nymph.

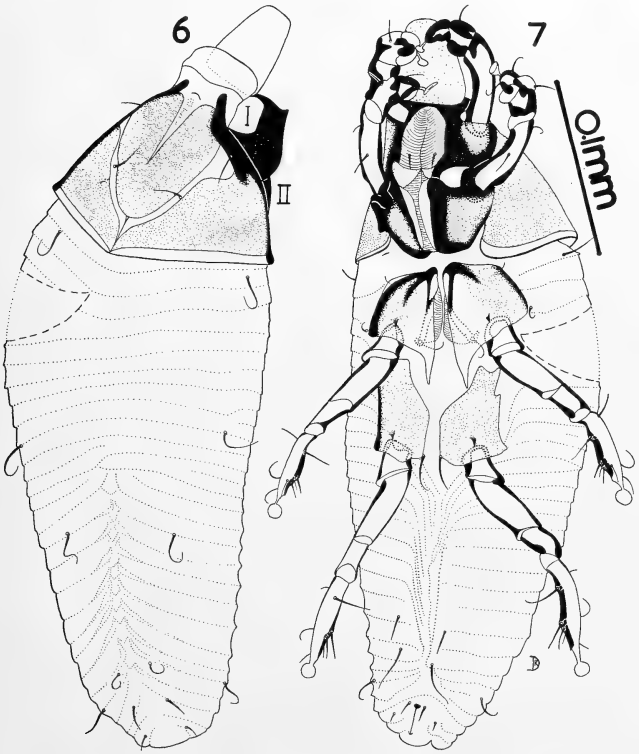
Length 373μ.

Material examined.

Six females, three males, and one nymph, labelled "On ring-tail, Woodbury, 28.v.54, Entomology Div., Dept. Agr., Tas., I. Rowley coll."

AUSTROCHIRUS ENOPLUS, n.sp. (ενοπλος, armed).

Types: Holotype female, allotype male, thirteen paratype females and six paratype males in collection of Queensland Institute of Medical Research, Brisbane. Also three pairs of paratypes in South Australian Museum, Adelaide. All specimens collected from *Hydromys chrysogaster reginae* Thomas and Dollmann, Flying Fish Point, North Queensland, 18.v.55.



Text-figs. 6, 7.
Austrochirus enoplus, n.sp. 6, Female, dorsal; 7, female, ventral.

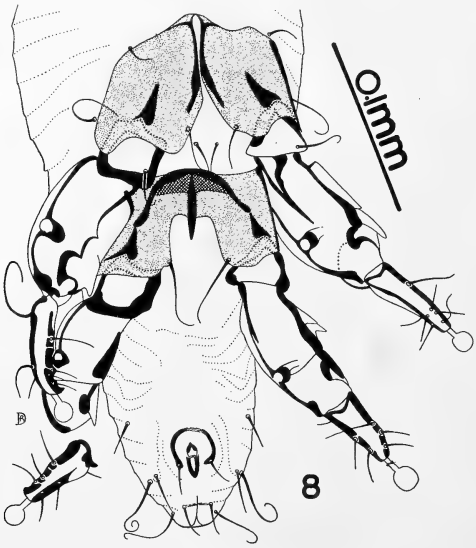
Female.

Dorsum with well sclerotized anterior shield, which is divided into three distinct regions. Mid-dorsal area deeply and narrowly incised medially, and flanked by four simple setae. Lateral areas densely sclerotized anteriorly, and becoming narrower as they pass behind the median area to meet centrally. The lateral areas encroach quite broadly onto the venter above coxae II.

Mid-dorsum with about ten simple cuticular annulations, the remainder of the dorsum being covered by annulations which form a pattern medially. Dorsal cuticle with seven pairs of simple setae, and without long terminal setae. The annulations pass ventrally, and behind coxae IV they run back medially to form a furrow. Three pairs of setae are present ventrally in addition to four flanking the terminal, longitudinal anus.

Ovum single, elongate, with almost parallel sides and rounded ends, average size 214μ long, 64μ wide; range 204 by 60 to 221 by 68μ.

Legs I and II very strongly sclerotized, flattened, with retrorse knobs and distinct caruncles. The clasping organ is transversely striate, with a pair of setae between coxae II. Coxae III not joined, with antero-median angles rounded and sclerotized, and postero-median corners transparent and produced into large pointed lobes. A pair of setae are present beneath these lobes, and also a pair of accessory transverse-striate



Text-fig. 8.
Austrochirus enoplus, n.sp. Male, ventral.

clasping organs. Two setae are present directly above the dorsal margin of coxae III, and a further seta above these just behind the ventral encroachment of the dorsal shield. Legs III simple, tarsi III with about eight setae. Coxae IV not joined, broad and sclerotized, with a seta at inner posterior angle. Leg IV similar to leg III, tarsus IV with about seven setae. The other movable segments of legs III and IV have no setae. Articulatory processes for legs III and IV small.

Average length 448μ, range 404 to 498μ.

Male.

Similar to female dorsally and anteriorly. Ventral annulations irregular, with three pairs of setae in addition to four flanking anus. Genitalia surrounded by sclerotized arc, which bears a seta at each posterior end. Intromittent organ between these two setae, short, sclerotized, and projecting backwards.

Legs III and IV greatly enlarged and heavily sclerotized, with long transparent flaps along ventral margin, and with peculiar looped sclerotizations dorsally. Basal

movable segment of leg III with a single seta, but leg IV without such a seta. Tarsi with small internal apical hook in lateral view, and normal caruncles. Tarsus III with strong curved seta basally, and about seven smaller setae. Tarsus IV with about six setae. Articulatory processes for legs III and IV larger than in female.

Average length 449μ, range 404 to 482μ.

Distribution.

Known only from the type host and locality in North Queensland.

Discussion.

There are two other described species of *Austrochirus*, both of them also Australian—*A. queenslandicus* Womersley, 1943 (genotype) and *A. sminthopsis* Womersley, 1954. Although the three species are readily separated on several characters, they fit easily into the genus, having a number of points in common—a single antero-dorsal shield, the median lobe of which is surrounded by four setae, a strong curved apical seta on tarsi I and II, a similar basal seta on tarsus III of the male, legs III and IV noticeably enlarged in the male of two species. *A. enoplus* and *A. sminthopsis* both have a three-lobed dorsal shield, but I believe the former to be more closely related to *A. queenslandicus*. The relationships are shown in the following key.

Womersley's two species are known only from marsupials of the families Phalangeridae, Peramelidae and Dasyuridae, while the species described above was taken on a rat. The three undescribed species in the Trouessart collection are all from dasyurids.

Key to species of Austrochirus *Womersley.*

1*a*. Cuticle of both sexes covered with small pointed papillae; male with legs III and IV not noticeably enlarged ..... *A. sminthopsis* Wom.

1*b*. Papillae, if present, flattened and scale-like, and confined to venter of female; male with legs III and IV enlarged and heavily sclerotized ..... 2.

2*a*. Only median lobe of dorsal shield present; postero-dorsal annulations not forming a median pattern; end of body with long setae. Female without accessory claspers between coxae III, but with scale-like markings on venter. Male without looped sclerotizations on dorsal edge of legs III and IV ..... *A. queenslandicus* Wom.

2*b*. Median lobe of dorsal shield enclosed by two lateral lobes; postero-dorsal annulations forming a pattern medially; end of body without long setae. Female with accessory claspers between coxae III but without scale-like markings ventrally. Male with looped sclerotizations on dorsal edge of legs III and IV ..... *A. enoplus*, n.sp.

Acknowledgements.

I am indebted to Mr. H. Womersley for the opportunity to redescribe and figure *Campylochirus chelopus*, and for the loan or gift of type and paratype material of his two described species of *Austrochirus*. Dr. Marc André kindly allowed me to examine the three undescribed Australian species attributed to *Campylochirus* from the Trouessart collection, and provided a list of relevant species still present in that collection. Dr. W. A. McDougall kindly identified the host of *Austrochirus enoplus*.

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PHYSIOLOGIC SPECIALIZATION IN CROWN RUST OF OATS.

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Synopsis.

Studies on physiologic race specialization within the organism causing crown rust of oats, *Puccinia coronata avenae* F. & L., are presented from field collections made in eastern Australia during the period 1952-54. These studies were conducted on the new differential set of ten varieties devised by North American workers with the object of assisting plant breeders in a more direct manner. Whilst assessing its merits for local conditions, studies were also continued on the former set.

These investigations revealed a considerable range in pathogenicity. Eight races were recorded on the new and ten on the former set. Of particular importance was the occurrence of a race attacking the variety "Victoria" within either series. This was first detected in the field on the variety "Vicland", but now occurs on other varieties. Its geographical range has continued to increase and at the present time occupies a wide area. Races attacking another important source of resistance, "Bond", are still found occasionally in the field, but do not appear to increase to any extent. A race attacking the varieties "Trispernia", "Landhafer", "Santa Fe" and "Mutica Ukraine", which were specifically introduced for breeding against rust, was found at Castle Hill Research Station, in very small amounts on adult plants of these varieties. This race is peculiar to the Australian continent and has been assigned race No. 286 by the central authorities at Ames, Iowa, U.S.A.

In view of the changes in the varieties used in breeding for resistance the new set has greater merit in assisting plant breeders. It is suggested that it should be used for Australian determinations with the inclusion of the extra-differential variety "Klein", and certain others in the former set, for determinations of local biotypes. Difficulties in biotype nomenclature within races are discussed.

In view of the absence of the alternate host plants (*Rhamnus* spp.) in Australia and the absence of experimental proof that heterocaryosis produces variability for pathogenicity, changes in virulence can only be accounted for by step-wise mutation. In certain instances mutations for pathogenicity may apparently encompass more than one varietal source of resistance.

Aspects of breeding for resistance include suggestions for incorporating genes by interspecific hybridization, experimental production of host plant mutations for resistance within economic varieties and the use of combined resistances to give more permanence in the usefulness of newly released economic varieties.

As a factor affecting oat production in New South Wales, crown rust, *Puccinia coronata avenae* F. and L., is of perhaps greater importance than stem rust, *P. graminis avenae* E. and H. Infections are especially severe in coastal areas. Frequently young crops are ruined before grazing is possible. The need for crown rust resistant varieties is also paramount in coastal areas of Queensland. Advanced oat crops heavily infected with crown rust lodge badly and ripen prematurely.

In general, breeding for crown rust resistance had received little attention in economic breeding programmes throughout Australia until recent times. In recent years a strain of "Victoria" × "Richland" named "Vicland" was introduced from the United States into Queensland, crown rust resistance being derived from "Victoria". Other varieties grown commercially on account of their crown rust resistance have been "Fultex" (a "Fulghum" × "Victoria" derivative introduced also from the United States) and "Klein 69B", which has had some resistance in New South Wales. In Queensland the resistance of "Klein" has not been regarded as high, but it has been observed that the first pustules on this variety appear a week or so later than those on varieties such as "Algerian" (Dr. L. G. Miles, personal communication). The variety "Bovah" was released by the Queensland Department of Agriculture and Stock in 1953; it was selected from a three-way cross between ("Bond" × "Victoria") × "Hajira" (Miles and Rosser, 1954). It therefore has two crown rust resistant varieties, Bond and Victoria, in its pedigree.

Review of Literature on Physiologic Specialization Studies.

As with all cereal rusts studied in any detail, physiologic specialization has been shown to occur in *P. coronata avenae* and to be of considerable importance in oat breeding programmes. Hoerner (1919) was the first to demonstrate physiologic specialization in the fungus and described four races. He distinguished these by the types of infection produced on two differential oat varieties, "Ruakura" and "Green Russian". Different workers in both North America and Europe then described various races showing that the phenomenon of physiologic specialization was widespread. Murphy (1935) isolated 33 races of crown rust of oats from collections obtained in the United States, Canada and Mexico. He demonstrated that the 33 races embraced all those isolated by previous North American workers, and proposed a standardized numerical designation for them. In Europe, Straib (1937), using 15 varieties, differentiated 142 races in Europe. However, Murphy and his associates at Iowa State College, Ames, Iowa, U.S.A., have been recognized as the centre for race identification and assignment of race numbers to appropriate cultures. The key to some 113 races was supplied by them in 1953. These races are primarily of North American origin, but include races identified in other parts of the world.

In Australia physiologic race surveys have been carried out by Waterhouse. For this purpose the standard set of differential hosts selected in 1931 by Murphy and Peturson (Peturson, 1935) has been used. Five races were described by Waterhouse (1938) and the Australian situation in general has been most recently summarized by Waterhouse (1952), where the distribution of races in time and space is indicated. These latter results covered a survey from 1935 to 1951. Thirteen races were described, race 6 constituting 50 per cent. of the determinations. Race 40 was first described by him, and races 102, 103 and 104 were new records, not being recorded elsewhere.

Inherent with these determinations are problems common to all rust physiologic race studies. It has frequently been observed that environmental modifications may markedly affect the reaction of a particular race on a pure line of a variety of the host plant. Temperature particularly has an effect in the case of crown rust; a low or resistant seedling reaction at lower winter temperatures may become a susceptible one at higher temperatures. On this account it is generally considered that the proper separation of races can only be carried out satisfactorily under relatively low temperature conditions. Since environmental factors influence infection type, it is possible that races described as distinct in different regions may actually be the same. Conversely, environmental differences may result in cultures described as the same constituting different races at lower temperatures. Doubtless all determinations should be made by a central authority under controlled conditions, but such a procedure is often impracticable. At the same time it is recognized that certain resistant reactions are little influenced by temperature. For example, the resistant reaction of the variety "Bond" seems little affected by increase in temperature. Peturson (1930) published critical data showing the effect of temperature on host reactions.

Introduction of New Differential Set.

The initial differential set of varieties selected in North America by Murphy and Peturson and used almost universally, including those for Australian determinations, comprised thirteen varieties belonging to different species of *Avena* as follows:

Avena sativa L.: Ruakura; Green Russian; Hawkeye; Anthony; Sunrise.
A. sativa orientalis Alefeld: Green Mountain; White Tartar.
A. byzantina C. Koch.: Red Rustproof or Appler; Sterisel; Belar; Bond; Victoria.
A. strigosa Schib.: Glabrota.

These varieties constituted a wide range in genotypes for studying reactions of different collections and hence determining the range in variability of the pathogen. However, at a recent conference of North American plant pathologists it was decided, commencing with the 1951 collections, to use a new revised set of differential oat varieties for crown rust determinations. There were indications that the varieties

previously used were inadequate for race identification, and it was not considered that the old differential set gave the help needed by plant breeders in a breeding programme for incorporating crown rust resistance into agronomic varieties. The need for a new differential set arose from a wide search for new genes for resistance to crown rust when resistances previously used proved susceptible to certain races. This has particularly applied to resistances derived from the varieties "Victoria" and "Bond". A race of crown rust capable of attacking "Victoria" was first reported by Murphy and Levine (1936) from a collection made in Texas. This race and others capable of attacking "Victoria" apparently were of no serious consequence in the field. However, in North America varieties possessing the "Victoria" type of crown rust resistance proved susceptible to a new soil-borne blight disease, Victoria blight, caused by *Helminthosporium victoriae* M. and M. The universal susceptibility of all varieties possessing the "Victoria" type of crown rust resistance to Helminthosporium blight indicated a close association between the "Victoria" type of crown rust resistance and blight susceptibility. On this account the growing of varieties in North America with the "Victoria" type crown rust resistance was discouraged; these varieties included "Garry" and "Beacon" in Canada, and "Vicland" and "Tama" in the United States. It has been recently shown by Welsh, Peturson and Machacek (1954) that resistance to race 4 and certain other races is controlled by a single dominant gene which is linked with susceptibility to Victoria blight in strains of "Victoria" parentage. In the case of race 45, and certain other races similar to it in inheritance, resistance is conditioned by three dominant genes. The authors found one of these factors to be one for a weaker type of resistance, similar to that shown to race 4, which appeared to be linked with susceptibility to Victoria blight. A factor for high resistance to the race 45 group apparently is not associated with Victoria blight susceptibility.

Attention was then turned to "Bond" as a source of crown rust resistance by oat breeders as it possessed resistance to Victoria blight. In the United States, however, "Bond" and its derivatives proved susceptible to three new races—34, 45 and 57. These races were at first sparsely distributed, being found chiefly in the southern United States winter-oat area. Race 45, however, increased in prevalence and caused considerable losses in the north-central portion of the winter-oat area. Newly released varieties, such as "Clinton" and "Benton" with "Bond" resistance to crown rust and outstanding agronomic qualities were severely attacked. This led to a search for new sources of crown rust resistance. The varieties "Trispernia", "Landhafer", "Santa Fe" and "Mutica Ukraine" were considered to be of great value in this connection. "Trispernia" was introduced from the Botanical Gardens, Cluj, Roumania, into North America. "Landhafer" was introduced into the United States from Germany under the name "Landhafer aus Uruguay", and probably originated in South America. "Santa Fe" originated in South America as a pure line selection made from an unnamed commercial oat variety. "Mutica Ukraine" was introduced into the United States from Russia in 1930 and the name subsequently shortened to "Ukraine". Information on the origin of these varieties is obtained from Welsh *et al.* (1953). These four varieties were included in a new differential set of ten varieties to test their reactions to collections of crown rust and hence anticipate their usefulness to oat breeders. In the new differential set, "Anthony", "Victoria", "Appler" and "Bond" were retained from the old set and the varieties "Bondvic" and "Saia" were added, so that the new set comprises the following varieties:

A. sativa: Anthony; Santa Fe; Trispernia; Ukraine; Bondvic.
A. byzantina: Bond; Landhafer; Appler; Victoria.
A. strigosa: Saia.

Under the new system of race designations, races are given new numbers commencing at 201.

The problems confronting Australian oat breeders have been remarkably similar to those in North America. Waterhouse (1952) described two races, 45 and 57, capable of attacking "Bond". In the spring of 1951 the variety "Vicland" at Lawes, Queensland,

was observed attacked by crown rust. This collection was susceptible on "Vicland" and "Victoria" seedlings in tests conducted by Professor Waterhouse. This race, as indicated later, has considerably increased in distribution since 1951. Victoria blight has also recently been reported from Queensland (Miles and Rosser, 1954).

These circumstances have necessitated a similar need to that experienced in North America for new sources of crown rust resistance. In this connection Australian breeders have largely been guided by North American experience, since the problems have been parallel. The varieties "Landhafer", "Trispernia", "Santa Fe" and "Ukraine" are being used in this country for crown rust resistance breeding programmes. It seems desirable to give the present information on race designations and host plant reactions for assistance to oat breeders throughout the Commonwealth and also for comparison with overseas race designations on the new differential set. A survey of 1952 to 1954 collections as to location and race will be presented in a separate paper when the testing for the current season is completed.

Procedure in Race Determinations.

Seedlings of both the old and new differential sets were inoculated when the first leaf was two to three inches in length, as described by Murphy (1935). After moistening, rubbing and remoistening the leaves, rust inoculations were made with a flat needle or by the bulk inoculation method. In the latter method uredospores from well-infected pots were dusted onto pots of seedlings, which were then incubated in a moist chamber for approximately 36 hours. As inoculations were done at relatively low temperatures, this incubation time rather than a shorter one was adopted. Different cultures were maintained in separate glasshouses as far as practicable to prevent contamination. After incubation the pots were stood on well-lighted benches. During higher summer glasshouse temperatures, use was made of a temperature-controlled, artificially illuminated chamber. Use was also made of this chamber for critical comparative reactions under constant environmental conditions throughout the year. The chamber was illuminated by batteries of fluorescent lights suspended about three feet over the benches. The tubes were about two inches apart and the intensity in the region of the plants was determined to be 400 foot-candles. Four-feet daylight type tubes were used, but the light from them was found to be deficient in the red end of the spectrum and caused a tip-burning of the oat seedlings. The quality of light in this region was supplemented by incandescent bulbs—four of 100 watts each being supplied per battery. Readings indicated that the light intensity was not appreciably increased. The temperature was controlled thermostatically by air blown over a refrigeration unit. The temperature was maintained at 65° F. with a variation of ± 2° F.

Infection types on host plants were designated according to the scheme outlined by Murphy (1935), which is based on that described by Stakman, Levine and Bailey (1923) for *P. graminis avenae*. For mesothetic reactions the symbol X, which is now more conventionally used instead of M, was adopted. Plus and minus signs were used to indicate variation within a given type, and the superscript symbols ^{c} and ^{n} to indicate chlorosis and necrosis respectively. Infection types were recorded approximately twelve days after inoculation and checked three days later.

If sufficient inoculum was available on the original collection, sets were immediately inoculated. If only a small amount was available, the collection was first built up on susceptible varieties such as "Burke" and "Richland".

Experimental Results.

Reaction of Races and Collections on New Differential Set.

Seed of varieties in the new differential set was made available by Dr. H. C. Murphy in 1952. Cultures maintained at Sydney University and new accessions were then tested on both the new and old differential sets. The reactions on the new set are tabulated in Table 1, together with the old race designations.

From the present position of varieties in commercial cultivation the detection of a race of crown rust (race number 259) capable of attacking "Victoria" has been disturbing. As previously indicated, this collection was first received from Queensland in 1951 on leaves on the variety "Vicland". In subsequent years the race has become more widely distributed in southern Queensland and has been prevalent on the north coast of New South Wales, occurring on varieties other than "Vicland". In November, 1954, "Vicland" was observed carrying appreciable crown rust at Parkes in the Central West of New South Wales. Invariably rust from "Vicland" has proved capable of attacking Victoria seedlings.

As Victoria blight has now been recorded in Queensland, and with the wider distribution of the "Victoria"-attacking crown rust race, this variety must be considered of doubtful value in oat breeding programmes.

TABLE 1.

Typical Reactions of Certain Races of P. coronata avenae *Expressed as Means of Rust Infections.*

New Physiologic Race No.	Mean of Reactions on New Differential Set of Varieties.										Old Physiologic Race No.
	Anthony.	Victoria.	Appler.	Bond.	Landhafer.	Santa Fe.	Ukraine.	Trispernia.	Bondvic.	Saia.	
203	4	1n	4	4	;	;	4	1	1	;	45, 57
226	4	1n	4	0;	;	;	4	1	1	;	1, 6
230	;	1n	4	0;	;	;	4	1	1	;	20
237	4	1n	4	0;	;	;	;	1	1	;	1, 6, 102[1]
238	;	1n	4	0;	;	;	;	1	1	;	7, 40, 103 (or 46)
240	4	1n	2	0;	;	;	;	1	1	;	9
259	4	3	4	0;	;	;	4	1	1	;	114
286[2]	4	1n	3	0;	4	4	4	4	3	;	6

[1] Race 102 on Saia is noted as a 2 type reaction.

[2] Race first recorded in present investigations and number assigned by central authorities, Ames, Iowa, U.S.A.

Of extreme importance also was the culture maintained at Sydney University as B.C. 37. This was collected on leaves of the variety "Trispernia", late in the season in the spring of 1953, in the field at Castle Hill Research Station, near Sydney. Only occasional susceptible pustules were found on a few plants of this variety and the possibility of such plants being not true varietal types was considered. However, such pustules transferred to seedlings of "Trispernia" gave rise to complete susceptibility on every plant. Seedlings of "Landhafer", "Santa Fe" and "Mutica Ukraine" when tested were also found to be susceptible. The differential variety, "Bondvic", was also moderately susceptible, whereas two of the parents in its pedigree, "Bond" and "Victoria", showed characteristic resistant reactions. In this respect it resembles race 233 overseas. The reactions of this collection on the new differential set were submitted to Dr. M. D. Simons, Ames, Iowa, U.S.A., for race designation. He reported that this was the first record of this race in any part of the world, and assigned a new race number, 286, to it. In view of the importance of this race, careful observations were made in the field during the 1954 season especially on differential rows at Castle Hill, where crown rust infection reached epiphytotic proportions. Susceptible pustules were found late in the maturity of the plants on "Trispernia", "Landhafer", "Santa Fe" and "Ukraine". In addition "Bond", "Victoria" and "Ruakura" were also observed carrying fully susceptible pustules. "Ruakura" is resistant to the common race, race 6, on the former differential set. The identification of these 1954 isolates has not been completed owing to the high summer temperatures and the limited capacity of the light room. The characteristic resistant reactions of the important differential varieties in both the seedling and adult stages is indicated in Table 2. The effect of temperature on seedling reactions is also shown in this table.

The variety "Klein 69B" was included in the differential sets since it has a measure of resistance against most crown rust races in the field. In 1952 an isolate from susceptible adult plants of this variety was collected in the field at Dundas, in the Sydney metropolitan area, by Professor Waterhouse, and exhibited a fully susceptible seedling reaction, assessed a (3^+) type as a mean reaction. The characteristic seedling reaction given by isolates to which adult plant resistance is shown is a low mesothetic (X^-) type. On host reactions this collection was designated as race 237 on the new differential set or race 6 on the former. Amongst 1954 collections, however, a few cultures were observed conforming to race 237 which gave a mesothetic reaction on "Klein 69B". Hence, by use of the variety "Klein 69B", two biotypes of race 237 can be distinguished, one attacking this variety and another showing moderate seedling resistance. In field collections, the more common conforming to race 237 has been that giving the higher seedling reaction on "Klein". It has occurred frequently in mixtures with race 259 from southern Queensland on susceptible varieties other than those having "Victoria" as a source of crown rust resistance. Collections on "Victoria" and "Vicland" have invariably conformed to race 259 reactions.

TABLE 2.

Characteristic Resistant Seedling and Adult Plant Reactions of Certain Differential Oat Varieties to Certain Australian Races of Puccinia coronata avenae.

Variety.	Seedling Reaction.		Adult Plant Field Reaction.
	Low Temperature.	High Temperature.	
Trispernia	1^-	2^-	$1^{n\,1}$
Landhafer	;	1^-	Immune
Santa Fe	;	1^-	Immune
Victoria	1^{-n}	1^n–2^-	Immune
Ukraine	;	2^-	Immune
Bond	0;	0;	Immune
Ruakura	1^-	2^-	1

[1] Characterized by rapid teleutospore formation.

Most collections conforming to race 6 exhibit the lower mesothetic reaction on this variety, however, since race 6 on the former differential set constitutes by far a greater proportion of determinations than does race 237 on the new set.

No other races have as yet been separated into biotypes on "Klein" and isolates capable of attacking this variety are on the current differential set diagnosed as race 237 or on the former as race 6. It seems probable that mutation phenomena are responsible for the changes in pathogenicity observed in the fungus, and on this basis "Klein" may separate other races into additional biotypes, and it is therefore included in all sowings of differential varieties. The resistant mesothetic reaction is more difficult to read than other reactions, but is quite characteristic and with experience can be easily assessed. There is no evidence to indicate that the mesothetic type of reaction is influenced more by changes in environment than any type influenced, for instance, by temperature changes. The (X^-) type of mesothetic reaction at higher temperature was rated as an (X^+), but never as a (3) or (4) type.

The variety "Ukraine" gave reactions which are worthy of comment. It was initially observed that collections made from Castle Hill and other field centres on adult plants of susceptible varieties where "Ukraine" itself was resistant gave susceptible seedling reactions on this variety. Adult plants subsequently tested in the glasshouses with these collections showed resistance. It appears, therefore, that "Ukraine" has in its genotype a factor or factors conferring adult plant resistance. It was observed, however, that at the same time certain races, as indicated in Table 1, gave seedling resistance on

"Ukraine", characterized by a fleck reaction. Race 237, previously mentioned, is a case in point. Adult plant tests with the biotypes of race 237 attacking "Klein" in both seedling and adult plant stages exhibited, as expected, "Ukraine" resistance. Races 238 and 240, collected in low proportions, also exhibit a completely resistant seedling reaction on "Ukraine". The nature of the inheritance shown by the seedling and adult plant factors in "Ukraine" and their association is being investigated in appropriate genetical studies.

In view of the importance of "Bond" in the differential set, since it has been, and still remains, one of the most widely used sources of resistance in crown rust resistance breeding programmes, some observations on the behaviour of this variety are pertinent. The two races, 45 and 57, capable of attacking "Bond" were both recorded in 1949 (Waterhouse, 1952) from collections made in the central coast region. They have occurred sporadically since, race 45 being recorded from the central tablelands in 1950, but, apart from this instance, races capable of attacking "Bond" have been restricted to the central coast area near Sydney, until 1953, when two collections from other areas showed a mixture of races on "Bond". From the mixtures, race 57 was isolated, the collections being sent from Raymond Terrace and Coff's Harbour, thereby showing a wider distribution for this race. In 1954, adult plants of "Bond" were quite heavily infected towards the end of their growing season at Castle Hill, but the occurrence of "Bond"-attacking races in the field is sporadic and infrequent. In this connection it will be of considerable interest to follow the behaviour of the variety "Bovah", which has "Bond" in its parentage. The "screening" effect of "Bovah", if collections capable of attacking "Bond" appear in appreciable proportions, will be of particular importance.

TABLE 3.

Typical Reactions of Certain Physiologic Races of P. coronata avenae *Expressed as Means of Rust Infections.*

Old Physiologic Race No.	Mean of Reactions on Old Differential Set of Varieties.													New Physiologic Race No.
	Ruakura.	Green Russian.	Hawkeye.	Anthony.	Sunrise.	Victoria.	Green Mountain.	White Tartar.	Red Rustproof.	Sterisel.	Belar.	Bond.	Glabrota.	
1	4	4	4	4	4	1n	4	4	4	4	4	0;	0;	226, 237
6	1	4	4	4	4	1n	4	4	4	4	4	0;	0;	226, 237, 286
7	4	4	;	;	4	1n	;	;	4	4	4	0;	0;	238
9	1	1	3	4	2	1n	4	4	2	1	1	0;	0;	240
20[1]	4	4	4	;	4	1n	;	;	4	4	4	0;	0;	230
40	4	4	;	;	4	1n	4	;	4	4	4	0;	0;	238
45	4	4	4	3	4	1n	3	3	4	4	4	4	0;	203
46 (or 103)[2]	4	2	;	;	4	1n	;	;	4	4	4	0;	0;	238
57	1	4	4	4	4	1n	4	4	4	4	4	4	0;	203
102	;	;	4	4	4	1n	4	4	4	4	4	0;	0;	237
114[3]	1	4	4	4	4	3	4	4	4	4	4	0;	0;	259

[1] First Australian record.

[2] By the commonly accepted definition of resistant and susceptible reactions, race 103 first described by Waterhouse corresponds to race 46 first described by Murphy. Further explanation in text.

[3] Race first recorded in present investigations and race number assigned by central authorities, Ames, Iowa, U.S.A.

Race Identification on Former Differential Set.

Race identification was continued during 1953 and 1954 on the old as well as the new differential set of varieties. This was considered desirable to enable a comparison to be made of the range of pathogenicity exhibited on the two sets and to assess their relative merits to pathologists and plant breeders. The races identified on the former differential set from field collections since 1952 are shown in Table 3. In general they are rather similar to those described by Waterhouse (1952) for previous Australian

races. Race 20 is a newly described race for Australia, being first described by Murphy at Iowa. It is characterized by a resistant reaction on "Anthony" and the two varieties of *A. sativa orientalis*, "Green Mountain" and "White Tartar". It also differs from the most prevalent race, race 6, in its susceptibility on "Ruakura". This collection was forwarded from Taree in New South Wales.

Races 3, 45, 47, 77 and 104 described by Waterhouse (1952) have not been identified during the past two seasons. Race 45 is included in Table 3, however, as it is maintained as a stock culture at Sydney University. Collections attacking "Victoria" have all conformed to one race, which differs from race 6 solely in its ability to attack this variety. The reactions on the former differential set show that it is a new race not described in the Iowa key and was formerly described as Sydney University B.C. 30, but, as indicated in Table 1, it conforms to race 259 under the new scheme. When the reactions were submitted to the authorities at Ames, Iowa, race number 114 was assigned to this race peculiar to Australia in race determination investigations. The reaction on "Victoria" is of a (3) type, but is clearly a susceptible one. Race 6 was again the most prevalent race, followed by races 1 and 114. Others comprised a small proportion of the determinations, but are important in revealing the variability in the crown rust organism.

Certain collections were found to conform to race 46 or 103. If the commonly accepted definitions of resistant and susceptible reaction types are adopted, then these two races are similar. Race 46 was first described by Murphy, and 103 subsequently by Waterhouse (1952). Differences in reaction types are recorded on certain varieties. For example, the reaction types on "Green Russian" are recorded as (0) and (2) respectively; other more minor differences are shown on other varieties. Aspects associated with minor variations in host plant reaction types owing to environmental modifications have already been discussed; on this basis it is perhaps better to consider the two races as corresponding to one another. This point is later referred to and discussed.

As found by Waterhouse (1952), a large proportion of collections have comprised more than one race, and as many as three races have been separated from one collection using the former differential set. With additional varieties from the new set these could be separated further. For example, one collection from wild oats submitted from Hermitage, Queensland, comprised a mixture of races 1, 6 and 7. It gave, in addition, a mixture of resistant and susceptible reactions on "Ukraine" which subsequently showed that race 6 could be further subdivided into two biotypes. On the new differential set the collection comprised a mixture of races 226 and 237. Mixtures of races 1 and 6 (distinguished by their reaction on "Ruakura") were common; the mixtures of races 237 and 259 recorded from Queensland particularly have been noted.

The mixture of races from the one collection appeared to indicate that there was no significant correlation between the amount of inoculum used and the amount of mixing revealed on the differential varieties. The presence of mixtures of races may have various implications. It may indicate the existence of a high mutation rate in the fungus or little competitive effect between races on a common susceptible host. The details of the groupings in mixtures will be presented when current season's surveys are complete. It is worthy of note, however, that mixing occurs on cultivated varieties and on species of wild oats.

Comparison of Race Identification on the Two Differential Sets.

It is apparent from an inspection of Tables 1 and 3 that all collections could have been adequately designated as to race number on the original set either from the key for identification of previously described races or with the new number supplied by the central authorities for the "Victoria"-attacking race. The former set, because it contains more varieties, and a greater number of genetic factors concerned with crown rust reaction, permits the expression of a greater range of variability in pathogenicity. In the present instance eleven races were described on the old set (ten occurring from field collections during the 1953–54 period) compared with eight on the new. However,

a variety such as "Ruakura" is of no importance in a breeding programme, although it separates races 1 and 6. Similarly, contrasting reactions of resistance and susceptibility with certain races were observed on varieties such as "Hawkeye", "Anthony", "Sterisel", "Red Rustproof" and "Green Mountain", which are of little direct economic importance or as sources of crown rust resistance. The reactions on these varieties are, however, of interest in academic studies, particularly with reference to the origin of new races. The reactions on "Belar" and "Sunrise", since they are grown in field areas, become more pertinent from the plant breeding viewpoint. It is of interest to observe that the two "side"-oat varieties belonging to *A. sativa orientalis*, "Green Mountain" and "White Tartar", react differentially to certain races, showing that varieties within this subspecies possess different genotypes with regard to crown rust reaction. In no instance have varieties belonging to the 7-chromosome species, *A. strigosa*, proved susceptible to crown rust, so that under Australian conditions they may prove of value in interspecific hybridization for transferring resistance to cultivated varieties in the 21-chromosome species. Many races attacking these varieties have been found in other countries, however, and there is no reason to suppose that they will remain resistant in this country in the future in view of the present variability exhibited by the fungus.

The new differential set obviously enables more satisfactory coordination in an oat breeding programme since the reaction on more varieties used as sources of crown rust resistance is shown. Race 286, apparently now of limited distribution, would, for example, have been assigned to the most prevalent, widespread and initially described race (race 6) on the former set, and the implications in the breeding programme not realized.

In any case it must be conceded that an arbitrary set of differentials, necessarily restricted in number, gives only a "rough" sorting of pathogenic entities into physiologic races. Profound differences in reaction type were observed by Waterhouse and Watson (1941) between two cultures of *P. graminis tritici* determined to be race 34 on the standard differential wheat stem rust set, one culture from the U.S.A. and the other from Australia, when additional varieties were added to the set. The recognition of this fact makes it obvious that the same sources of resistance to what are described as similar races may not be equally effective in two different centres. The use of a differential set permits only valid comparison on the varieties within that set without additional implications. Sources of resistance used by plant breeders should always be included for testing with local collections. It is agreed that the use of extra varieties will often sort apparently similar races into distinct biotypes, recognized as a lower category in designation. With an additional variety or varieties, what are apparently identical "physiologic races" on the accepted set of differential varieties can frequently be differentiated into further categories, designated as "biotypes" of that particular race. The same term is used in a different sense for a collection which consistently gives a minor variation on a differential variety from the reaction which is regarded as characteristic for the race. There is no guarantee that the term "biotype" is used in a strict genetic sense in these cases, but biotypes (of a race within a particular geographical region) may be regarded in general as similar until their reactions are shown to be different on a certain additional variety.

In any case, as Waterhouse (1952) points out, the distinction between a "physiologic race" and a "biotype" is an arbitrary one, and a satisfactory system for designating the rust entities has yet to be formulated. Waterhouse, in the present citation, suggests various schemes with comments. In the present instance, the writers consider that the use of suffixes "A" and "B", after the race number indicating resistance and susceptibility respectively, when the additional variety is clearly stated, is satisfactory, providing the reservations previously mentioned are kept in mind. It is considered to represent a compromise between a scheme attempting world-wide coordination on a standard and universal differential set and one where the sole emphasis is on sources of resistance utilized in plant breeding programmes in a particular country. Obviously the most accurate basis for race determinations is that where genes for resistance are used,

rather than a selected set of varieties whose genotypes are not known for reaction. The genetics of the resistances in the differential varieties are being investigated at Sydney University with this ultimate objective in mind.

However, from the viewpoint of a comparison of race identification on the two differential sets, some attempt to link up investigations already carried out and races recognized on the former set with current investigations on the revised set seems desirable to preserve continuity in crown rust physiologic race investigations. For this reason both sets were, as indicated, sown for side-by-side comparisons, whilst the relative merits of race determinations on the revised set were being assessed.

Cultures described in Tables 1 and 3 are further shown in Table 4, where the reactions on varieties in both the former and new differential sets and the extra differential variety "Klein" are indicated. On this scheme 15 distinct rusts were clearly separable. In certain instances varieties outside the appropriate differential sets were incapable of further subdividing races into biotypes. For instance, varieties outside the former differential set failed to show that race 9 could be subdivided into biotypes. This culture was designated as race 240 on the new set and the former differential set likewise failed to reveal entities within this race. Races 1 and 6 were both shown to be composed of distinct biotypes when different collections of these races were tested on the new differentials and "Klein"; in this connection the varieties "Landhafer", "Ukraine" and "Klein" acted as extra differential varieties. Race 1 was shown to comprise two biotypes, one attacking "Ukraine"; to the second, "Ukraine" was resistant. Race 6 was shown to be composed of four biotypes. In this instance the reactions on the three varieties mentioned above outside the differential series were needed to designate these biotypes. Three of these biotypes gave a resistant reaction on "Landhafer"; to two of these, "Ukraine" was resistant and these two were finally separable by their differential reaction on "Klein".

Since, as previously indicated, the cultures were designated by only eight races on the new differential race numbers, it is apparent that varieties in the former differential set were in more instances capable of sorting these new races into biotypes than was the situation in the reciprocal direction. Biotypes were not distinguishable within races 240, 259 and 286. The remaining five were constituted of two or more biotypes. The varieties in these instances serving the function of extra differential varieties were "Ruakura", "Green Russian", "Hawkeye", "Green Mountain" and "Klein". In the case of race 237 three extra differential varieties were needed for biotype separations.

It is recognized in some instances that varieties previously referred to could have been replaced by others to serve the same purpose in biotype separation. For example, "Santa Fe" could have equally well separated race 6 into biotypes as did "Landhafer". If these two varieties have identical genotypes to Australian rusts, then they obviously serve equally well. On the other hand, if the genes for resistance are not identical, there is the possibility of further separating biotypes by the inclusion of the two varieties.

Further complications in biotype nomenclature become immediately apparent with the inclusion of differential reactions on more than one variety outside the particular differential set under consideration. Waterhouse (1952) pointed out certain aspects of these considerations and suggested that letters A and B could be again used for contrasting reactions of resistance and susceptibility on the second variety (the suffix BA or BB, for instance, following the race number) or the letters C and D used alone. In either case there is nothing to show which variety is used for the first separation or which for the second.

In the present instance the authors suggest the use of the letters A and B, C and D, E and F, etc., for contrasting reactions on the first, second and third, etc., extra-differential variety respectively. In this way there is no need to include reactions on extra-differential varieties unless pertinent, and if a key is appended to the race determination table the situation can be readily comprehended. Unless the situation is

TABLE 4.

Typical Reactions of Certain Physiologic Races of Puccinia coronata avenae *Expressed as Means of Rust Infections.*
Mean of Reactions on Differential Varieties.

Varieties Common to both New and Former Differential Sets.				Varieties in New Differential Set Only.						Varieties in Former Differential Set Only.									Variety Outside Differential Sets.	Physiologic Race No.		
Anthony.	Victoria.	Appler or Red Rustproof.	Bond.	Landhafer.	Santa Fe.	Ukraine.	Trispermia.	Bondvic.	Saia.	Ruakura.	Green Russian.	Hawkeye.	Sunrise.	Green Mountain.	White Tartar.	Sterisel.	Belar.	Glabrota.	Klein.	Former.	New.	Proposed International.
4	1[n]	4	0;	;	;	;	1	1	;	4	4	4	4	4	4	4	4	0;	X⁻	1 C	237 F	237 Anz 1
4	1[n]	4	0;	;	;	4	1	1	;	4	4	4	4	4	4	4	4	0;	X⁻	1 D	226 F	226 Anz 2
4	1[n]	4	0;	;	;	;	1	1	;	1	4	4	4	4	4	4	4	0;	X⁻	6 ACM	237 EHM	237 Anz 3
4	1[n]	4	0;	;	;	4	1	1	;	1	4	4	4	4	4	4	4	0;	X⁻	6 AD	226 E	226 Anz 1
4	1[n]	4	0;	;	;	;	1	1	;	1	4	4	4	4	4	4	4	0;	3⁺	6 ACN	237 EHN	237 Anz 4
4	1[n]	4	0;	4	4	4	4	3	;	1	4	4	4	4	4	4	4	0;	X⁻	6 B	286	286 Anz 1
;	1[n]	4	0;	;	;	;	1	1	;	4	4	;	4	;	;	4	4	0;	X⁻	7	238 K	238 Anz 1
4	1[n]	2	0;	;	;	;	1	1	;	1	1	3	2	4	4	1	1	0;	X=	9	240	240 Anz 1
;	1[n]	4	0;	;	;	4	1	1	;	4	4	4	4	;	;	4	4	0;	X⁻	20	230 J	230 Anz 2
;	1[n]	4	0;	;	;	;	1	1	;	4	4	;	4	4	;	4	4	0;	X⁻	40	238 L	238 Anz 2
;	1[n]	4	0;	;	;	4	1	1	;	4	2	;	4	;	;	4	4	0;	X⁻	46 (or 103)	230 I	230 Anz 1
4	1[n]	4	4	;	;	4	1	1	;	4	4	3	4	3	3	4	4	0;	X⁻	45	203 F	203 Anz 2
4	1[n]	4	4	;	;	4	1	1	;	1	4	4	4	4	4	4	4	0;	X⁻	57	203 E	203 Anz 1
4	1[n]	4	0;	;	;	;	1	1	;	;	;	4	4	4	4	4	4	0;	X⁻	102	237 EG	237 Anz 2
4	3	4	0;	;	;	4	1	1	;	1	4	4	4	4	4	4	4	0;	X⁻	114	259	259 Anz 1

A–B Landhafer resistance vs. susceptibility.
C–D Ukraine resistance vs. susceptibility.
E–F Ruakara resistance vs. susceptibility.
G–H Green Russian resistance vs. susceptibility.
I–J Hawkeye resistance vs. susceptibility.
K–L Green Mountain resistance vs. susceptibility.
M–N Klein resistance vs. susceptibility.

clearly stated, confusion could readily occur in any scheme envisaged. For instance, an investigator in one country could assign certain designations to his entities, similar to those used elsewhere, where different extra-differential varieties had been employed. This further emphasizes the need for a central authority on a world basis to control and standardize physiological race studies on pathogenic organisms. Environmental modifications have, in addition to the problem herein discussed, been referred to previously; besides, there is always the possibility of genetic differences between stocks employed by different investigators.

Using the scheme suggested, race 6 was clearly divisible into four biotypic entities, viz., B, ACM, ACN and AD. Since the first biotype is clearly set apart by its susceptible reactions on "Landhafer", there appears little need to record reactions on the other extra-differentials—in this case "Ukraine" and "Klein". Likewise the fourth and last entity is shown to be distinct by its susceptibility on "Ukraine" in contrast to the second and third, and reactions on "Klein", whilst of importance in plant breeding, are not necessary in defining this biotype. The reaction on "Klein" can be readily determined by reference to a table of complete reactions. This variety is, however, necessary to categorize the second and third biotypes of race 6. Letters to designate seven contrasting reactions are indicated in Table 4.

Any procedure which enlarges the group of differential varieties increases the work involved, and some critical thought must be given to the extent to which extra-differential varieties can be added to race determination sets. This problem must be faced in the case of crown rust of oats. All varieties in the former differential set with the exception of Glabrota give contrasting reactions to one race or another, but they serve in many instances to illustrate variability in the organism without having any plant breeding significance. In any case there seems little need to include both varieties of *A. strigosa*—"Glabrota" and "Saia"; both are resistant to all Australian collections to which they have been tested. It has been regularly noted that "Glabrota" gives a lower reaction of a sharp "0;" type, whereas the "Saia" typical reaction is a ";" type with more pronounced necrosis associated with the reaction. This suggests that the factors for resistance are different in the two varieties, but this point must await genetic analysis.

Watson (1955), in race nomenclature, has used the suffix "Anz" after the race number, followed by numbers to indicate the number of biotypes of a particular race in the New Zealand and Australian geographical region. Since there is evidence that interchange of spore material can occur across the Tasman Sea, these two countries logically comprise one isolated geographical area. Such a scheme immediately indicates the location of a race under discussion, and implies that the reaction on varieties outside the differential set may show two races bearing the same number in different areas to be distinct. The present discussion is, however, somewhat different, in that a comparison is being attempted between the merits of the two differential sets. The rust designations under Watson's system with the new race scheme are shown in Table 4, and it is proposed from now on to adhere to this scheme to conform with overseas work, and in addition make the determinations of the utmost value to plant breeders. For brevity and international coordination this seems the best procedure to be followed.

Origin and Nature of Variability in the Crown Rust Organism.

In Australia, the alternate hosts, *Rhamnus* spp., obviously do not play an important part in the origin of new races. Species of this genus are restricted in distribution to Botanic Gardens. In England, the buckthorn, *R. catharticus* L., native to Northern Asia, is important in the production of new physiologic races (Griffiths, 1953). In the northern spring-oat areas of North America, including Canada, this species is important for the same reason (Welsh *et al.*, 1953). The uredospore stage does not overwinter, and infections are attributable to aecidiospores from the buckthorn, or uredospores which are windborne from the Southern United States area, where the rust overwinters on oats and grasses. Native species of buckthorn in North America, although they can

be infected artificially by germinating teleutospores, are not considered of the same importance as the introduced *R. catharticus*, since they are usually not found near oat fields (Melhus *et al.*, 1952).

Attempts have been made to germinate teleutospores in this country, but the results in general have been disappointing. It has been found that spores formed under cooler temperature conditions which favour teleutospore germination in other rusts have been no more prone to break their dormancy, either when frozen in the refrigerator or exposed to winter conditions on the Tablelands. Germination after the initial freezing has not been encouraged by alternate thawing and freezing, although this procedure has been of value with other cereal rusts. Waterhouse (1952), however, reported the successful germination of teleutospores of race 6 and infection with production of spermogonia and aecidia on *R. catharticus* from which uredospore cultures were obtained on oats, thus completing the life cycle of the rust.

In the absence, in the first place, of the alternate host plant and also owing to the sporadic germination of teleutospores in any case, other means of reinfection of crops annually in Australia must be examined. It is apparent that oat plants, either self-sown ("volunteer") or belonging to the wild oat species, can be found infected at all seasons of the year. This particularly applies to the coastal areas; for instance, at Castle Hill oat plants can be always found carrying crown rust. By this means uredospores are considered to reinitiate new infection sites in cultivated crops. The culture of oats, with early sowing for grazing in the summer, also means that oat crops are grown for at least ten months of the year in many districts. It is generally considered also that spread by windborne uredospores from southern Queensland, where crops mature earlier, occurs in a southerly direction into New South Wales.

The role of grass species in the carry-over of *P. coronata avenae* is not completely known. Collections of *P. coronata* on *Lolium* spp., a rust which is particularly widespread and at times reaches epiphytotic proportions, have repeatedly failed to attack several varieties of oats normally susceptible to *P. coronata avenae*.

Murphy (1935) found certain wild-grass species outside the genus *Avena* susceptible to the six races of *P. coronata avenae* to which they were tested. *Dactylis glomerata* L. gave a variable reaction but was completely susceptible to one race. Although this grass is an important pasture plant in Australia, crown rust is uncommon on it, and it has only once been observed infected with *P. coronata* by the writers. Collections of *P. coronata* from *Holcus lanatus* L. and *Polypogon monspeliensis* (L.) Desf. have proved incapable of attacking oats; Waterhouse (1952), in addition, found a similar result with crown rust on *Agrostis avenacea* Gmel. Hence these must be regarded as different subspecies of *P. coronata*. However, much more remains to be done in determining the importance of native and introduced grasses in the carry-over of *P. coronata avenae* and in clarifying the taxonomic affinities of the subspecies of *P. coronata*.

Since the alternate host is for all practical purposes absent in Australia, new races appear to arise by mutation or by nuclear interchange in the dicaryotic phase. In studying the role of the latter phenomenon as a cause of rust variation, many workers have cultured dissimilar races of rusts together on fully susceptible varieties for many transfer generations without observable new recombinations of nuclei in the fungus. Waterhouse (1952), for example, cultured two such races of *P. graminis tritici* for twenty transfer generations without any new race being detected. He suggests, however, that particular associations of races may show affinities which lead to nuclear interchange. A recent abstract by Nelson and Wilcoxson (1954) is important in this aspect of variation. When uredospores of two or more races of *P. graminis tritici* were mixed on compatible and non-compatible wheat varieties and the resulting generation of spores transferred to resistant varieties, new biotypes were produced which differed from parent races in pathogenicity and/or colour. A particularly virulent biotype on the formerly highly resistant Khapli variety was, however, markedly unstable and after more than 30 generations was completely avirulent. Dissociation occurred on Khapli and apparently the virulent biotype was 3–4 nucleate compared with the normal avirulent

binucleate condition. Such biotypes may, therefore, perhaps be considered as of no great importance in nature.

If hyphal anastomoses are of importance in the production of new biotypes or races, then the crown rust organism is offered many opportunities for this to occur in nature. Besides recombination which may result from haploid nuclear interchange in a pure culture of a single genetically heterozygous race, mixtures of races in a single collection on the one oat leaf are quite common and allow possible recombination between different races. Waterhouse (1952) commented on the prevalence of mixtures in collections studied, and some features of findings in present studies in this connection have already been presented, although the results during the past two years are not as yet completed for statistical compilations. With regard to the present aspect, it is pertinent to record that differential varieties such as "Ruakura", "Green Russian", "Hawkeye", and "Anthony" have given, quite often, a mixture of susceptible and resistant reactions on the one leaf, from which particular races have finally sorted out.

In view of the entirely hypothetical role which can be ascribed to vegetative recombination, mutation is the most logical phenomenon to explain the variability encountered in the crown rust organism. The evidence for this, whilst circumstantial, is suggestive. One would expect mutational processes to encompass successively single sources of resistance. Watson and Singh (1952) have pointed out the probable occurrence of stepwise mutations in the case of stem rust of wheat under Australian conditions. This is similarly exemplified in the case of race 114, which differs from race 6 in the present studies solely in its ability to attack "Victoria". Further, since race 6 is the most prevalent Australian race, from race survey studies one would expect a genetical change to be more likely to occur in this race and be subsequently detected. There is no reason to suspect that such mutations have not occurred before. In this instance the variety "Vicland" has obviously produced a "screening effect" which favours the new type. Reference to the physiologic race tables accompanying this paper show many other instances of races differing solely in reaction on one variety. In the case of mutations affecting varieties whose genotypes have been of no importance in economic breeding programmes, there is, of course, no such selective advantage. In these cases it may be that mutant types are better competitors on uniformly susceptible varieties. Competition studies in this respect have been reported by Watson (1942) and Watson and Singh (1952). The last-named reported that newer types originating, presumably, from mutation, with a wider host range, were in general poor competitors. This further suggests that similar mutation may have occurred before but failed to be maintained owing to competition. In the case of varying reactions exhibited on "Ruakura", for example, particular environmental conditions previously may have favoured in competition the new types capable of attacking it, in spite of the absence of a "screening effect", since this variety is of no importance economically. At the present time, however, environmental conditions may enable both types to exist together, apparently even on the one plant in certain instances, without a strong competitive effect. One final observation on these aspects is that mutations for avirulence could, of course, occur as well; they would be readily apparent since avirulence is dominant in general in other rust organisms studied genetically. It is feasible that mutations for pathogenicity may also have other physiological effects on the fungus, or that physiological effects may be due to mutations which produce no associated observable pathogenic changes. An analysis of the biotic factors concerned in competition trends would be of great interest; in the case of race 34 of wheat stem rust which rapidly replaced previously existing races in Australia (Waterhouse, 1929), Waterhouse (1939) suggested that the predominance of this race was explicable on two bases. Firstly it had a wider host range than the other Australian races, and, secondly, new crops of uredospores were produced more rapidly, enabling reinfection to occur earlier.

It is difficult in the laboratory to simulate the role nature can play on such a large scale in the field. Attempts are being made to produce mutations by irradiating the fungus, but the amount of material which can be handled in this way is limited, and

may not approach in effect the significance of much lower mutation rate under natural conditions. Likewise anastomosis producing nuclear recombination is obviously offered larger opportunities over field areas to produce pathogenic changes.

Obviously the phenomena responsible for variability within the fungus will be better understood when the genetics of the pathogen have received further study. Such considerations as the dominance relationships of virulence *versus* avirulence, and the number of factors for pathogenicity in each case, are extremely important in discussions on mutation phenomena. Similarly the genetics of host plant resistance is important in such considerations, and this is a major part of the work being carried out at Sydney University at present.

There appears little evidence to support the hypothesis of adaptation by the rust to previously semi-resistant varieties. This hypothesis is based on the possibility that a race can adapt itself for full susceptibility to the environment imposed by its growth on a partially resistant variety.

Aspects Associated with Breeding for Resistance.

The advent of a race capable of attacking the variety "Victoria" and the susceptibility of varieties deriving their resistance from this source to Helminthosporium blight has made it of doubtful value as a parent in breeding for crown rust resistance under Australian conditions. This is particularly so in view of the wide distribution of this rust race, as revealed in the current survey and the seed-borne nature of Helminthosporium blight.

"Bond" likewise is suspect as a parent in breeding as it is susceptible to certain races. In this case the races do not appear to be widespread but apparently still persist annually in small amounts. Since the Queensland variety "Bovah" has "Bond" and "Victoria" as sources of resistance, it will be of the utmost importance to follow its behaviour in field areas. To date it has proved resistant to collections to which it has been tested. Certain overseas races shown on the key for identification attack both "Bond" and "Victoria". Griffiths (1953) also reports such a race.

Whilst race 286 is of limited distribution at the present time, it has extremely serious repercussions on any projected breeding programme. It attacks the varieties "Landhafer", "Trispernia", "Santa Fe" and "Ukraine", which have been specifically recommended and introduced as newer sources of resistance. The uniform susceptibility of these four varieties would indicate that they possess similar genotypes to Australian races to which they are resistant, or at least to the race from which 286 arose, presumably by mutation. However, the evidence from genetical studies indicates that this is unlikely. Local studies as yet incomplete (Baker and Upadhyaya, 1954) indicate that "Santa Fe", "Trispernia", and "Ukraine" have factors for resistance which are either closely linked or allelic, but that the single gene in "Landhafer" is different and independent genetically. These in general are the findings of Finkner (1954), except that his work suggests that in the case of the first three varieties two factors are operative in certain instances when race 57 is used. A differential reaction is shown by these varieties to certain overseas races, indicating that the factors for resistance are different in these cases. Presumably, therefore, race 286 differs from other races in possessing at least two new pathgenes if there is a gene-for-gene relationship between resistance in the host and virulence in the pathogen as shown by Flor (1954) to be the case in flax rust. It is difficult on a genetic basis to explain the moderate susceptibility of "Bondvic" to this race; however, Dr. M. D. Simons (personal communication) indicates that North American workers also have not been able to explain the behaviour of this variety on what might be expected from its parentage.

The variety "Klein 69B" is of doubtful merit as a source of resistance in view of its occasional susceptibility to biotypes in New South Wales and almost universal susceptibility in the field in Queensland, where rusts capable of attacking it seem to be more widespread.

The problems in breeding for crown rust resistance in oats are in a general way similar to those in breeding for resistance to other cereal rusts. In the case of wheat stem rust in Australia, the need for genetic diversity in sources of resistance has become obvious, as commercial varieties having a common source of resistance have simultaneously become susceptible to a new rust. Various suggestions to anticipate changes in the rust flora have been made in recent times. Watson (1949) suggested that prior preparation for the occurrence of new rusts could be undertaken by a backcross programme where single genetically different sources of resistance were added to appropriate commercial varieties. Borlaug (1954) advised the cultivation of a "composite variety" in this connection, made up of a mixture of backcrossed lines carrying different genotypes for resistance, the mixture being adjusted and altered according to the prevalence of particular rust races or biotypes. Watson and Singh (1952) outlined a scheme based on combined resistances where backcrossed lines are combined in one genotype to produce a derivative containing two genes, each of which controls resistance to all local rusts. Mutations affecting single loci would not become established, and the two sources of resistance would have to be affected simultaneously, which event would be expected to be highly unlikely on a probability concept. There is the possibility, however, that several host genes may be affected in the one mutation in the fungus, as shown by Newton and Johnson (1939) in the case of wheat stem rust. It has already been noted in this connection that in the present instance race 286 presumably arose by mutation and affected at least two genetically different sources of resistance. Hence combined resistances in certain cases may be of hypothetical value only. However, this method appears to offer the best means of breeding for resistance at the present time, provided the resistances are chosen with care, and no varieties having either single source of resistance are released to facilitate the step-by-step increase in virulence range.

Two other possibilities may be mentioned of value in breeding for resistance to crown rust. One is the transference by wide crossing to incorporate resistance from other species, such as *A. strigosa* (n = 7), varieties of which have been found resistant to all Australian isolates. Successful hybrids have been made by the authors between cultivated varieties (n = 21) and *A. barbata* (n = 14); such hybrids were highly sterile, and it is also probable that hybrids between *A. strigosa* and cultivated varieties are more difficult to accomplish. In any case, as previously noted, American races are capable of attacking this species and such interspecific hybridization may alone increase the range of genetic diversity and confer no permanent resistance in itself under Australian conditions.

The second point is the recent report by Browning and Frey (1954) on the production of stem rust resistant oat lines from irradiated seed of a rust susceptible variety. Certain strains were produced in the fifth generation following irradiation, which were resistant to more than one race and were agronomically desirable. Since only four hundred seeds were originally treated, this procedure may be of practical value in breeding for crown rust resistance.

Discussion and Conclusions.

Results of physiologic race studies herein presented indicate a great range of variability in pathogenicity in the crown rust fungus, presumably owing to step-wise mutation for increasing virulence. Causes of variability in the field are indicated as difficult of simulation under experimental conditions in the laboratory. It is obvious that more knowledge is needed on the genetics of the pathogen and of the host plant to secure fundamental information on the cause and possible range of variation in pathogenicity. To facilitate studies on the former aspect, problems associated with sporadic germination of teleutospores of Australian races are urgently in need of investigation. It is possible that in the absence of any role on the alternate hosts, Australian rusts may have lost the ability for ready teleutospore germination, but Waterhouse's results with other cereal rusts, and even *P. coronata avenae* itself, do not confirm this. Perhaps freezing to lower temperatures of −5° C. may encourage germination, and this possibility

is being investigated. The fact that crown rust occurs on volunteer and wild species of *Avena* means that teleutospores can be collected over a wide seasonal range but no particular season for formation seems to result in improved germination. As suggested by Waterhouse (1952), different races may vary in ability for teleutospore germination. The genetics of host plant resistance is being investigated in great detail, on the other hand, and the results will shortly be presented to clarify the Australian situation. However, much more remains to be done before the host-pathogen genetic relationships are established on a basis comparable to that in flax rust, where Flor (1946, 1950) has established fundamental relationships in this connection.

The situation as regards the future in breeding for resistance is not particularly straightforward. Combined resistances before races of wide pathogenicity become established in the field seem to offer most promise. Genes from interspecific hybridization may increase genetic diversity in this respect. If results similar to those reported for stem rusts in oats can be obtained in the case of crown rust, irradiation to produce resistance in desirably agronomic varieties should not be neglected.

Sampling to indicate the distribution of races and biotypes in space and time needs to be intensified. Owing to limits on time and available assistance, some modification of the former differential oat crown rust set seems desirable to make the surveys of most use to plant breeders. It seems desirable to conform to the system of race nomenclature followed by North American workers, since their objectives are designed for results to be of utmost assistance in breeding programmes. At the same time certain varieties such as "Klein" might be added to separate Australian biotypes in view of their importance in the field; furthermore, varieties such as "Ruakura" which have served readily to separate Australian races on the former set might well be retained. As the amount of work which can be undertaken is limited, efforts should be directed to testing a larger number of collections on critical differentials rather than fewer on extra varieties of no breeding significance. The inclusion of a limited number of varieties from the former differential set would enable a certain amount of continuity to be maintained with previous local investigations; new race numbers would, at the same time, be in line with the central coordinating authorities in the U.S.A. and local biotypes could be indicated appropriately.

The growing of selected varieties in regions where crown rust is of importance would be of value in anticipating changes in pathogenicity in the field. Race 286, for instance, was detected by critical observation of a single row of the variety "Trispernia" at Castle Hill Research Station. Except for this instance, its presence would have remained undetected locally.

In view of minor modifications in reaction type produced by environmental influences, attempts to separate categories on anything more than a broad resistance and susceptible basis is considered to seek too much refinement unless reactions are compared with strictly comparable conditions by one central authority. The use of accurately controlled light chambers reduces such modification and enables determinations to be carried out when glasshouse conditions are unsuitable.

Stakman (1954) summarizes the position in regard to breeding for resistance to wheat stem rust thus: "Basic researches obviously are needed to determine the genetic potentialities for virulence in rust." In the case of crown rust of oats about which less is known, the need is obviously more paramount.

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NEW INFORMATION ON THE CORROBOREE FROG (*PSEUDOPHRYNE CORROBOREE* MOORE).

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[Read 26th October, 1955.]

Synopsis.

The original short taxonomic description of *Pseudophryne corroboree* was based on a single male spirit specimen in the collection of the Australian Museum, Sydney.

Through acquiring a large series of living specimens of this hitherto extremely rare frog, the author has been able to provide new information on the colour in life, on structure, habits in captivity, breeding habits, and on the egg and tadpole stages.

A correction has been made as to the type locality, which is in New South Wales, and not in Victoria as stated by Moore.

Historical.

Pseudophryne corroboree, the most brilliantly coloured species of the cryptozoic genus *Pseudophryne*, was first described by Moore (1953). Apart from being so outstandingly different in colour pattern from other members of the genus, the circumstances surrounding its discovery, and subsequent relevant events, are so decidedly unusual that they justify being put on record.

Moore (*loc. cit.*) "discovered" the type specimen (No. R13103), a male, in the collection of the Australian Museum, Sydney, New South Wales. The type locality, Towong Hill Station, near Corryong, Victoria, lies mainly on river flat country on the Victorian side of the upper reaches of the River Murray. It lies about 25 miles northwest of Mt. Kosciusko, and the height above sea-level is nine hundred feet. As will be shown later, this reported type locality is erroneous. The true locality is in New South Wales.

The type specimen was received by the Australian Museum in February, 1947, but, although it was obviously new, the Museum herpetologist, Mr. J. R. Kinghorn, felt that further specimens should be secured before a description could be undertaken. These were not forthcoming, and the frog remained undescribed until 1953, when it came under the notice of Dr. J. A. Moore, a visiting Fulbright scholar. Moore felt that in this instance he was justified in erecting a new species on a single specimen. Even allowing for the inevitable fading consequent upon a six-year sojourn in alcohol, the dorsal pattern with its broad stripes of black and pale yellow was still so strikingly different from that of any other known *Pseudophryne* (see figure in Moore, 1953) that he had no hesitation in making a new species. Apart from this single type specimen, other examples had been seen by the finder, Mr. Ossie Rixon, of Towong Hill Station. In a letter to Mr. J. R. Kinghorn he says: "They are rare but you do see them, generally about cattle pads."

During the Congress of the Australian and New Zealand Association for the Advancement of Science which was held in Canberra, A.C.T., Australia, in January, 1954, specimens of *P. corroboree* were found in sphagnum country in the upper regions of Mount Gingera (height 6092 ft.) near Canberra, which lies within the State of New South Wales. In this instance, the finder was the small son of Dr. M. J. D. White. The frogs were taken some distance below the summit, in boggy country, and were under logs and other debris. One specimen was sent to Moore who, in the meantime, had returned to his University at Columbia, N.Y. That brought the total number of known specimens in the possession of museums up to two.

Three days after this Gingera discovery, the author was presented with five living specimens of *P. corroboree* by Dr. A. Gunzburger, Engineering Geologist to the Snowy Mts. Hydroelectric Authority. These five came from an area between Island Bend (4000 ft.) and Smiggin Hole (5600 ft.) in the Snowy Mts. They were tracked down mainly by their call, and taken from burrows near a watercourse.

The acquisition of these five specimens marked the end of a long search, primarily instigated by Mr. D. G. Moye of the Hydroelectric Authority. Mr. Moye had seen Moore's paper in these PROCEEDINGS, and realized that the apparently rare *P. corroboree* actually occurred in some numbers in the Snowy area. They frequently came to light during bulldozing operations.

To the best of the present writer's knowledge, the total number of known specimens of *P. corroboree*, up till December, 1954, was seven, viz., the original type in the Australian Museum, Sydney, one at Columbia University, N.Y., U.S.A., and the author's five. To these, though, must be added an eighth, which was collected on Mt. Gingera, and sent to Mr. A. R. Main of the University of Western Australia at Perth.

In January, 1955, Prof. C. W. Emmens, of the Department of Veterinary Physiology, Sydney University, informed the author that a Sydney medico, Dr. A. E. Fraser Chaffer, had collected a hundred specimens of *P. corroboree* in yet another locality—near Alpine Hut, in the Mt. Kosciusko area. This happened in late December, 1954, and early January, 1955. The height above sea-level in this locality is about six thousand feet. The terrain here is decidedly boggy, and the frogs were taken from burrows, some of which were as deep as ten inches, in rotting vegetation beneath the surface growth of sphagnum moss.

Most of the first batch of about fifty, which were brought back to the hut, were eaten by a black snake. Fifty or so more were therefore collected, this operation requiring little more than half an hour. Many hundreds of the frogs could have been taken with ease.

Dr. Chaffer returned to the Alpine Hut area at Easter (April), 1955, but a vigorous search, extending over several days, yielded only four undersized examples of *P. corroboree*. The hundreds which had been there three months previously had disappeared. Their exact whereabouts is not known. The earlier specimens had all been taken in the vicinity of a tongue of land extending down from the main range of mountains, and surrounded on three sides by water. The frogs must have either burrowed down very deeply indeed in anticipation of the coming snows that will bury them for several months, or else they have left their marshy summer habitat for higher ground. In the course of both of his visits, Dr. Chaffer collected developmental stages. Further mention of these is made below.

He informs me that he has been aware of the existence of the corroboree frog for more than four and a half years, i.e., something like two and a half years *before* the appearance of Moore's original description. He saw his first specimen at Ryrie's Parlor, a little to the west of Alpine Hut, in December, 1951. It was not until November, 1954, that he learned of the great scientific interest associated with *Pseudophryne corroboree*. He points out that the true locality of the type specimen is not Towong Hill Station, Victoria, as stated in Moore's paper. The real locality is on one of the snow leases of this property—Round Mountain, sometimes known as Lett's Trig Station. This is on the upper reaches of the Tumut River in New South Wales. It lies 30–35 miles north-east of Towong Hill Station, and the height above sea-level is 5758 ft. The excerpt from the letter written to Mr. J. R. Kinghorn of the Australian Museum by the station owner, Mr. T. W. Mitchell (quoted by Moore, 1953), says that the type specimen "was found at the foot of a fence post at the foot of Round Mountain". The height, even at this reduced level, would be well above the snowline.

Another locality where specimens had been seen, but not collected, by station personnel, was at Fifteen Mile, which also lies in New South Wales, and is part of the old Kiandra goldmining field, 5–6 miles north of Round Mountain, and 4500–5000 ft. above sea-level.

It is thus apparent that Moore's paper should be restyled "A New Species of *Pseudophryne* from New South Wales", and the type locality changed from Towong Hill Station, Victoria, to Round Mountain, New South Wales.

What at first appeared to be a very rare new frog species turns out to be relatively common within the confines of its montane habitat.

It should be noted here that none of the local inhabitants who were shown the corroboree frog by Dr. Chaffer could say that they had seen one before. This is perhaps explained by the frog's burrowing habits which keep it out of sight most of the time.

Now that the matter of type locality has been cleared up, *P. corroboree* emerges as a cryptozoic species with a range restricted to high altitudes (4500 ft. and up) which are under snow for several months of the year.

An interesting problem that awaits further illumination is whether this species will be found in other elevated localities in New South Wales where similar environmental conditions (especially sphagnum bogs) are to be met with.

Colour and Other Structural Features.

a. Colour.

With the acquisition of living specimens, the author was able to make some observations of the true colours. The pattern of bold longitudinally disposed dorsal stripes shown in Moore's illustration (*loc. cit.*) is quite representative, although there are minor variations. The author has four of the original five living specimens presented to him by Dr. Gunzburger in January, 1954. The fifth specimen died unaccountably in September, 1954, and now reposes in the British Museum. In addition the author has eleven preserved specimens (*ex* Chaffer). These were given to him alive by Prof. C. W. Emmens, but died a few weeks later from an infection. The series is too small to give an adequate idea of colour variation or, more particularly, pattern variation, but it is large enough to allow some amplification of the description of the spirit specimen which is the type.

The black of the latter is, in life, a very shiny black, and the pale yellow a shiny bright yellow or yellow-orange. The dark blotches on the limbs and on the ventral surface are also shiny black in the living animal, but of the pale blotches some are yellow, some are mixed yellow and pale blue (each colour clearly defined), some are uniformly pale blue, and others are white.

For any given individual there are three typical combinations of black and pale areas, respectively, on the ventral surface, viz., black and yellow, black, yellow and pale blue, or black and white. The latter combination is very similar to the characteristic marbled pattern seen on the ventral surface of the related species, *P. australis* and *P. bibroni*.

It has been noticed that during the first month of winter of this year (1955) the pale blue blotches of the four surviving *P. corroboree* in the author's possession have turned white. These animals have been in captivity for more than eighteen months.

b. Body proportions.

Body measurements have been made on twelve preserved specimens. One of these is a post-metamorphic juvenile, and the others are sexually mature. All come from the Alpine Hut region near Mt. Kosciusko.

These measurements are given in Table 1, which also includes Moore's figures from the type specimen.

In four of the eleven adults, the fourth toe reached beyond the snout, in four of them it reached the snout, and in three it only reached as far as the anterior margin of the eye. In the juvenile specimen it reached beyond the snout. In one of the adults, the tibiotarsal articulation, in the adpressed limb, reached as far as the anterior edge of the arm. In eight of them it reached the armpit, while in two female specimens (Nos.

1 and 2) it fell notably short of the armpit. In one female (No. 1) it fell short by one-third of the distance from vent to armpit. In the juvenile it reached midway between the armpit and the eye.

c. Thigh muscles.

Noble (1922) has shown that the relationship of the distal tendon of the semitendinosus muscle to that of the combined gracilis major and minor is of considerable assistance in elucidating anuran affinities. He finds that there are two extremes here. In his "ranid" type, the distal tendon of the semitendinosus lies dorsal to the graciles, while in the "bufonid" type the tendon lies ventral to the latter.

TABLE 1.

Specimens ..	Type	1	2	3	4	5	6	7	8	9	10	11	12
Body length in mm.	24	31	27	25	25	25	26	25	25	25	26	26	8·9
Sex	M.	F.	F.	M.	M.	M.	M.	M.	M.	M.	M.	F.	Juv.
Length of tibia ..	7·9	8·5	8·7	9·2	9·2	8·7	7·5	8·3	8·7	7·5	7·5	8·7	1·9
Width of head at posterior end of jaws	7·0	9·7	8·3	8·3	8·3	7·7	7·5	7·0	8·3	8·0	8·5	8·5	3·3
Tip of snout to centre of nares	1·1	1·7	1·0	1·3	1·3	1·3	1·2	1·3	1·5	1·5	1·2	1·3	0·3
Centre of nares to anterior corner of eye	1·7	2·2	2·0	1·8	1·8	1·8	1·8	1·7	1·8	2·0	1·8	2·0	0·6
Antero - posterior eye measurement	2·2	2·5	2·3	2·0	2·5	2·5	2·3	2·5	2·5	2·0	2·0	2·0	1·2

F. = female. M. = male. Juv. = juvenile (post-metamorphic).

Parker (1940, p. 9) gives a table which shows that Australian leptodactylids can be divided into four groups with respect to this relationship. The two leptodactylid subfamilies, the Cycloraninae and the Myobatrachinae, show a complete gradation from one extreme to the other, but this gradation is in four definite steps. The bufonid type is found only in the Cycloraninae, and the ranid type in the Myobatrachinae. These are the extremes, but there are two intermediate conditions which presumably represent stages in the migration of the semitendinosus tendon from the superficial (bufonid) position to the deep and more specialized ranid one.

Thus in *Limnodynastes ornatus*, *Lechriodus melanopyga*, *L. platyceps*, *L. fletcheri*, and in *Adelotus brevis* (all Cycloraninae), as well as in *Uperoleia marmorata*, *Crinia georgiana*, *C. signifera*, *C. laevis*, and *C. tasmaniensis* (Myobatrachinae) the distal tendon of the semitendinosus perforates the gracilis complex. These species constitute Parker's Group II.

His Group III contains *Pseudophryne australis*, *P. bibroni*, and *P. coriacea*, as well as *Glauertia orientalis*. In these species, the distal tendon of the semitendinosus perforates the *ligamentous head* of the graciles. The members of his Group IV all show the specialized ranid condition, where the tendon of the semitendinosus muscle passes dorsal to the graciles. The species in this group are *Glauertia russelli*, *Metacrinia nichollsi*, and *Myobatrachus gouldii*.

The tendon relationships in *Pseudophryne corroboree* turn out to be particularly interesting, but, before going into details of these, attention is directed to the fact that, although tendon relationships are constant for any given species, not all species of the same genus necessarily belong to the same group. Compare for instance *Glauertia orientalis* (Group III) and *G. russelli* (Group IV).

In *Pseudophryne corroboree*, the gracilis major and gracilis minor muscles share a common distal tendon which is considerably narrower than the rather broad distal end

of the muscle body. This tendon, of the usual glistening white appearance, lies towards the inner margin of the combined muscle, and inserts in the knee. Attached to the lower end of the graciles is also a sheet of thin transparent connective tissue which passes downwards, covering the tendon of the semitendinosus as well as the proximal ends of the tibial muscles. (A histological preparation shows this to be areolar tissue.)

The tendon of the semitendinosus passes beneath, i.e., dorsal to the broad lower end of the gracilis mass, and inserts low down on the tibia. Throughout its course it is covered with the thin sheet of tissue mentioned above, but it does not perforate the ligamentous head of the graciles. In this respect *P. corroboree* differs from the other *Pseudophryne* species mentioned above, all of which are placed in Group III. *P. corroboree* has the typical ranid arrangement of the tendons, and must accordingly go into Group IV.

Other Observations on Living Specimens.

As previously noted, four *P. corroboree* have been successfully kept in the laboratory since January, 1954. They are housed in a ventilated, glass-topped wooden box measuring about 10″ × 8″. In the bottom of the box is a shallow copper tray, and the box is kept packed with damp moss to within an inch of the lid. The purpose of this is to concentrate the populations of the vinegar fly *Drosophila* which are used as food, and to bring them therefore within easy reach of the frogs. The latter have always fed very readily, and indeed seem to spend most of their time on top of the moss, even during the winter, looking for flies. The locomotion is definitely *Pseudophryne*-like, being in the nature of a rapid crawl. During the process the body is held on tiptoe. However, if they are suddenly disturbed, the frogs will make hops of four to six inches. Although normally cryptozoic, they swim quite readily when put into water. In general activity they resemble *P. australis* and *P. bibroni*, although unlike the latter species they do not "sham dead" when touched.

What they normally feed on can only be guessed at, but the author was most impressed by the eagerness with which they took both *Drosophila* and ordinary house-flies, right from the beginning. They will also feed readily on small black ants. Prof. C. W. Emmens, to whom I am indebted for this piece of information, tells me that his corroboree frogs, received from Dr. Chaffer, have thrived on a diet consisting solely of these small black ants.

When living food is introduced into the vivarium, the behaviour of the frogs is very striking. The males are much more alert and active than the females, and will often stalk flies before catching them. Although only small frogs (av. length *ca.* 25 mm.), they can accurately strike flies at distances from one-half to five-eighths of an inch. The "slapping" sound as the tongue returns to the mouth with its prey can be heard three feet away. When stalking a fly, the frog rises on tiptoes, and notable tremors pass along the rigidly held body right to the tips of the digits. As soon as food is introduced, and the males become aware of it, they begin to call loudly. This brings the remaining frogs out of their hiding places, and the flies are quickly snapped up.

Prof. Emmens also informs me that for a time he kept a mixed population of *P. corroboree* and *P. australis* in one vivarium. Males of *P. australis* would indiscriminately clasp with their own species or with male or female corroborees. The male corroboree frogs on the other hand only clasped with females of their species.

Breeding.

Attempts to stimulate ovulation by pituitary injection were not successful. The method used was that of Hamburger (1948), both males and female being injected with *Bufo* pituitary. On the final attempt, there appeared to be some reaction. The males became very active and called repeatedly, and the female dug a number of separate burrows in the moss. However, neither oviposition nor clasping occurred and the attempts were temporarily abandoned. The author was unwilling to use the more drastic method which involves sacrificing the animals in order to effect artificial insemination.

Dr. Chaffer has provided some valuable information on the breeding habits in the wild state.

The frogs were actively breeding during the second half of December and the early part of January. No information is available as to when this activity actually commenced.

The general pattern of breeding behaviour would appear to resemble that of the related *P. australis* and *P. bibroni*, in that the eggs are laid in burrows. If a subsequent shower of rain fails to materialize within a short time, the eggs proceed with their development up to a certain point and then just "wait" until they are washed into water. The latest intra-ovular stage secured by the author was an 18 mm. tadpole with spiracle and well-developed hindlimb buds.

The female *P. corroboree* makes her burrow in decaying vegetation under the sphagnum moss. These burrows may be up to ten inches beneath the surface. In the second half of December, 1954, opened burrows contained eggs as well as both parents. By the end of the first week in January, 1955, it was usual to find only one parent in the burrow with the eggs. The number laid is typically twelve. This is to be compared with the twenty-odd deposited by *P. australis*, and the ninety to a hundred eggs laid by the female of *P. bibroni*. It should be noted that adults of all three species are of the same order of size.

Harrison (1922) states that *P. australis* undergoes metamorphosis four weeks after hatching, whereas the larvae of *P. bibroni* require 5–6 months. He correlates the abbreviated development of *P. australis* with the fact that this frog lays its eggs by temporary watercourses which may dry up in a short time. *P. bibroni* on the other hand "lays its eggs about the margins of sluggish streams and stagnant ponds . . . has no need of undue haste" (Harrison, 1922). He also (*loc. cit.*) mentions that as long as *P. bibroni* eggs remain moist, they can last for four months out of water, in a state of suspended development.

The meagre amount of available information respecting the life history of *P. corroboree* suggests that it may follow the pattern of *P. australis*. The female lays a very small number of unusually large yolky eggs which are capable of going through to metamorphosis in a short time. If corroboree eggs fail to reach water shortly after being laid, there is some evidence (see below) that they, too, may reach an advanced stage of development and then "wait" for an indefinite period (that could well be several months) until the next rainfall.

A problem of considerable interest here is how eggs in a burrow ten inches beneath the surface of the moss could be washed out by a subsequent shower of rain. It seems likely that with enough rain the area containing burrows is inundated by a rise in level of water in the surrounding bog.

In Table 2 comparative egg-measurements are given for *P. australis*, *P. bibroni*, and *P. corroboree*. Regrettably, these measurements, through lack of sufficient material, are not all on similar stages.

Apart from the initial great swelling of the jelly, once the egg gets into water, the diameter of the vitelline membrane increases steadily as the contained tadpole grows. However, the stage of development is indicated wherever possible.

It will be noted that the newly spawned, unfertilized egg of *P. corroboree* was received by the author already preserved in 10% formalin. On this account the figure for the overall diameter is probably not that of the egg as it is laid. On the other hand, the measurement of the egg proper (3·5 mm.) would indicate that it is larger than the eggs of both *P. australis* and *P. bibroni* at a comparable stage. It will also be noted that in *P. bibroni* the jelly swells up to twice its original diameter after being put into water. All of the twelve *corroboree* eggs brought back from Mt. Kosciusko in Jan., 1955, by Dr. Chaffer were in an advanced stage of development when the author received them in Feb., 1955. They had been kept in a minimal quantity of water—little more than a film—for a month, and at the time of receipt were badly infected with *Saprolegnia*. The larvae were immediately freed from their membranes and set up in a small aquarium.

Prof. Emmens has informed the author that eggs of similar age hatched in a very short time when put into a suitable quantity of water.

Two tadpoles were fixed immediately after release from the membranes and measured respectively 11·6 mm. and 12·3 mm. This order of size is the earliest known at which hatching can occur. Only future work will show whether the tadpoles can come out at an even earlier stage. In the two tadpoles in question, the branchial chamber was obviously well developed on each side, but the spiracular passage was still in the form of an open horseshoe with very prominent raised edges, on the left side of the body. Further reference to this rather remarkable structure will be made below.

Of the remaining tadpoles, only two were salvaged in a sound condition for preserving. One of these had died six days after being freed from its membranes, and the other after twenty-two days.

TABLE 2.

Species.	Overall Diameter. (Millimetres.)	Diameter of Vitelline Membrane. (Millimetres.)	Remarks.
Pseudophryne australis	7·8	2·6	Harrison, 1922. Measurement made in water? "Ovum segmenting."
,, ,,	*ca.* 8·0–9·0	3·0	Present author. Much debris attached to jelly. Stage of closed neural folds.
,, ,,	9·1	6·8	Present author. Prehatching (?) stage.
P. bibroni	4·0	2·0	Harrison, 1922. Not yet in water? Stage?
,, ...	3·2–4·0	2·5–2·7	Present author. Newly spawned, not yet in water.
,, ...	7·8–8·5	3·3–3·6	,, ,, Morula stage, 15 hours later than foregoing. In water.
P. corroboree	6·0	3·5	Present author. Newly spawned but unfertilized. Specimen in 10% formalin, as received.
,, ...	7·1–8·3	5·1–6·0	Present author. Pre-hatching? Open spiracular channel. In water.

The length of the "6-day tadpole" was 16·3 mm., and that of the "22-day tadpole" was 18 mm., or slightly less than $\frac{3}{4}$". The other tadpoles, all of which died, were too badly mauled by their fellows to be of any use as material. The heavy mortality was probably due to unaccustomed high temperatures. The author is informed that even during the summer months, in their natural habitat, the water temperature seldom exceeds 10° C.

The six viable eggs collected by Dr. Chaffer at Mt. Kosciusko at Easter, 1955, all contained tadpoles ready to hatch—indeed their general appearance (on 20/4/55) suggested that they had been laid a long time previously, possibly even as far back as Dec., 1954. As soon as these eggs were put into water, and only the outer layers of jelly pricked, the tadpoles literally "fell" out of the enclosing membranes. The diameter of the egg proper at this stage was of the order of 5 mm. All of the yolk had been used up, and the spiracle was definitely established as a small opening on the left side of the body about halfway between the snout and the base of the tail.

Although of the same order of length as the "22-day tadpole" referred to above, viz., 18 mm., there had been a considerable change in body proportions especially in the body-tail ratio. In the 12 mm. tadpole the tail is approximately 1·5 times the length of the main body, whereas in the 18 mm. (Easter, 1955) tadpoles it is twice as long as the body. It looked even more than this due to the slimming-down of the body through yolk absorption.

These are very dark tadpoles. To the naked eye they appear almost black, but under the microscope narcotized specimens show a profusion of silvery chromatophores. These disappear after a short time in alcohol.

Owing to present restriction of material, only the main points of what appears to be a decidedly interesting method of spiracle formation will be touched upon.

In the earliest stages in the author's possession—tadpoles of 11·6 mm. and 12·3 mm. respectively (approximate age at least 39 days)—the right branchial chamber is completely closed in by the opercular fold. The left branchial chamber on the other hand communicates with the outside through a very well developed postero-lateral slit in the constriction between the head and the body. In one of the tadpoles, gill filaments are clearly seen, projecting through this slit. The latter is surrounded by a horseshoe-shaped depression on the skin. This depression, which has prominent raised edges, lies obliquely across the body with its "open" end directed anteriorly and ventrally. This "open" end almost reaches the midventral line.

Transverse sections of the 11·6 mm. larva show that a short connecting passage already exists, passing from the right branchial chamber, beneath the epidermis across the midline to open within the depressed area already mentioned. No trace of this opening was obvious in the whole specimen. At this stage, then, the only communication the right branchial chamber has with the outside is via this short narrow transverse passage. The left branchial chamber, on the other hand, communicates directly with the outside by the prominent slit already referred to.

In a 16·3 mm. tadpole, six days older than the foregoing, the horseshoe-shaped depression in the epidermis has increased enormously in extent. It is now broadly oval with particularly prominent raised edges, and appears to be "tunnelling" across towards the right branchial chamber. Within the area, the epidermis covering the yolk mass is particularly thin and the yolk shows clearly through. The slit-like opening to the pharynx on the left side is very prominent, and is partly occupied by gill filaments.

In an 18 mm. tadpole (the "22-day tadpole" referred to earlier) (approx. real age 61 days) the process of tunnelling has gone so far as to establish communication with the right branchial chamber. This is quite definite. The lower margin ("open end") of the depression has reached the midventral line. At this point it dips under as a wide circular passage leading into the right branchial chamber. It is possible to see right along this passage into the latter. Thus the right branchial chamber communicates with the outside by means of this wide passage. What has happened to the narrower one referred to above, which existed earlier, and which extended further across to the left side, is not known. Perhaps it is incorporated in this second, larger passage. This point will be cleared up when further material comes to hand. At the moment the author is unwilling to section his very scarce material.

The ultimate fate of the depressed horseshoe-shaped area must also await further research, as material is not available covering later stages.

The raised margins of the area are so prominent that the outline of the tadpole, as seen from above, is notably asymmetrical. A clue to the possible fate of the area is given by an abnormal tadpole of *P. bibroni*, described below.

It was possible to study branchial chamber formation in tadpoles of the two related species *P. australis* and *P. bibroni*. In both of these, the course of events was different from that observed in *P. corroboree*, and follows a more "typical" anuran path. In neither *australis* nor *bibroni* was there any suggestion of the depressed horseshoe-shaped area seen in *corroboree*.

At this point the author must put on record a very curious yet relevant fact. One embryo of *P. bibroni*, when at the "early tail bud" stage, developed a marked edema in the yolk region which became swollen to twice its original size. This embryo was freed from its membranes and kept under routine observation for a number of days. To the author's surprise, it acquired on its left side a *corroboree*-like depressed area which subsequently "tunnelled" across towards the right side of the body and the right branchial chamber. To avert the possibility of this obviously feeble larva dying and disintegrating before it could be adequately preserved, it was eventually killed and fixed. By that time, the margins of the depression had grown over and inwards towards

one another, and were clearly about to fuse to form a spiracular passage along the left side of the body.

Apparently the edema was enough to upset the normal processes of development and cause the *bibroni* larva to adopt this atypical mode.

It is quite likely that in *P. corroboree* the development of the spiracular passage follows a similar course. Unfortunately the next stages in the author's possession (collected at Easter, 1955) had the spiracular passage, and the spiracle, fully developed. It is hoped that intermediate stages will be forthcoming on an expedition to the Kosciusko area which is planned for December, 1955.

A further point of interest in the life history is that the adult coloration is acquired before metamorphosis. The colours, however, are fugitive in 10% formalin. The only specimen of a newly metamorphosed *P. corroboree* in the author's possession (No. 12 in Table 1) is of a fairly uniform dusky tint to the naked eye. Under the microscope, the black bands on the dorsal surface can be made out, but the formalin has changed the yellow colour to a dark brown. The ventral surface is almost uniformly dark brown. The limbs are pale brown with some traces of darker blotches.

Acknowledgements.

This work was carried out with the aid of a grant from the Research Committee of the University of Sydney, to whom thanks are due.

The author must also express his indebtedness to Mr. D. G. Moye and Dr. A. Gunzburger of the Snowy Mountains Hydroelectric Authority, to Professor C. W. Emmens of the Department of Veterinary Physiology of the University of Sydney, and to Dr. E. Fraser Chaffer for valuable material.

A special acknowledgement is due to Dr. Chaffer for information regarding breeding habits in the field, and the nature of the terrain in which the frogs are found.

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SOME EXAMPLES OF STREAM-DERANGEMENT IN THE KOSCIUSKO AREA.

By W. R. Browne, D.Sc., T. G. Vallance, B.Sc., Ph.D., and the late Harold Rutledge, B.Sc., Ph.D.

(Two Text-figures.)

[Read 30th November, 1955.]

Synopsis.

From the Kosciusko area above 6,000 feet there are described three examples of stream-derangement resembling stream capture, two involving tributaries of the Upper Murray, and the third a small tributary of the Upper Snowy. All the valleys concerned are glaciated, and it is thought that the apparent piracy resulted primarily from (*a*) the breaching of inter-valley ridges by valley-glaciers whose new paths were afterward followed by the post-glacial streams, and (*b*) the deposition of recessional moraines across the glacial valleys which produced stream-diversion.

Introduction.

Apart from the evidences of Pleistocene glaciation in which it abounds, the Kosciusko region is of interest for its geomorphology, and particularly for the way in which the development of its landforms has been influenced by the passage of ice.

The drainage-pattern is closely related in part to differential elevation in the late Tertiary Kosciusko epoch (Browne, 1952), and in part to the strike-directions of the belts of folded Ordovician quartzites and schists of which the region is partly composed, and to the gneissic foliation, shear-zones and joint-systems of the granite which is the dominant rock, but there are not wanting signs that drainage was to a minor extent deranged and topographical forms modified in consequence of glaciation.

The glaciation was made possible by the elevation of the region to its present altitude, and the Kosciusko uplift initiated a cycle of river-erosion, which caused rejuvenation of the streams; this erosion continued vigorously through Pleistocene time with local interruptions during glacial maxima, and is still proceeding. Three stages of glaciation, it would seem, were experienced; the marks of the second and third, a valley- and a cirque-glaciation respectively, are the most obvious.

There are indications that the courses of certain minor streams have been modified by the passage of valley-glaciers in such a way as to simulate the phenomena of river-piracy and water-gaps as produced by normal river-erosion. Three examples have come under our notice, all in the Tops country at elevations of more than 6,000 feet, where the activity of valley-glaciers was most vigorous. Two of the diversions have affected members of the Upper Murray system, the third a tributary of the Upper Snowy.

Diversion in the Upper Murray System.

(*a*) The Cootapatamba valley heads in the col or saddle known as Rawson Pass (6,930 ft.), some 500 yards E.S.E. of Mt. Kosciusko, which seems to have functioned as a kind of ice-divide whence valley-glaciers moved respectively north along one of the heads of the Snowy River and south towards the Murray along the Cootapatamba valley. This valley trends almost S.S.W. for about 1,100 yards and then S.W. for 1½ miles. Half a mile down from Rawson Pass in a recess in the right wall of the valley lies the shallow Lake Cootapatamba, which occupies the floor of a cirque belonging to the third glacial stage. It is dammed by, and perched on top of, two moraines, the upper confined mainly to the right or western side of the valley, while the lower stretches right across it. Cootapatamba Creek on the valley-floor flows well

to the east of the lake, which drains into it below the lower moraine. This has been breached by the creek and is seen to be resting on schist or phyllite.

The boulder-strewn valley is flatly U-shaped as far down as the lake, but below that is rather V-shaped, with a wide flare and steep gradient. Some 450 yards down

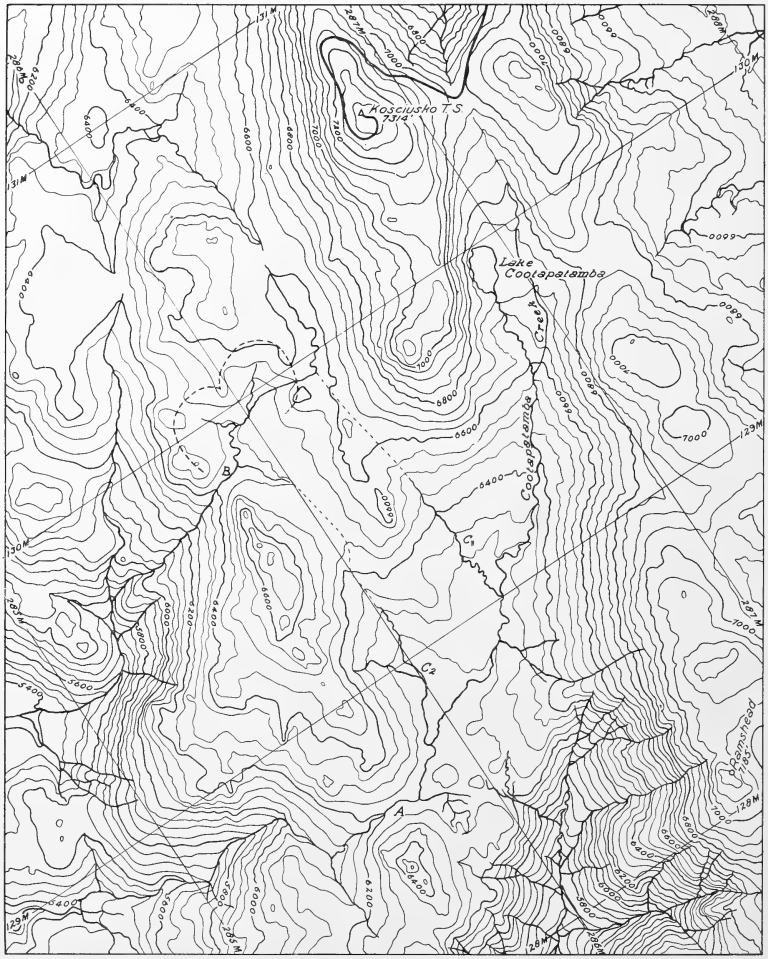

Fig. 1. A map of part of the Upper Murray drainage system. The length of the side of a square on the grid represents one mile. North is towards the top left. The lighter broken lines indicate the suggested original courses of creeks C_1 and C_2.

granite crops out along the floor in the form of three small low platforms, steps, or *roches moutonnées*. About one mile down from Rawson Pass the valley widens out once again and flattens, and the creek, perhaps as the result of increased erosive power following on the white man's occupation, has gouged out a trench 20 feet or

more deep to decomposed granite bedrock through coarse débris, probably in part glacial outwash from the Cootapatamba cirque-glacier and in part alluvium deposited by the post-glacial creek. A mile farther down the flat valley floor is heavily aggraded and in places swampy, and the creek is joined on its right bank by two small tributaries flowing from the north in wide but rather steep glacial valleys. The broad valley-floor here gives the impression of a former shallow rock-basin excavated below the junction of the main and tributary glaciers and later filled with detritus, and there is actually a low and inconspicuous southern rock-rim to the basin. A casual glance downstream suggests that the Cootapatamba valley continues on for a long way to the S.W., its eastern wall rising steeply to the Ramshead Range, which carries on southward to the limit of vision. But at 2½ miles from Rawson Pass the broad valley ends abruptly and gives place to the deep gorge of a headwater tributary of Leatherbarrel Creek, itself a tributary of the Indi or Upper Murray, while Cootapatamba Creek bears away to the right, pierces the western wall of its valley in a gap about 300 feet deep and 100 yards wide, and after maintaining its relatively low gradient for a few hundred yards begins to descend somewhat steeply over rapids into a great ellipsoidal bowl-like hollow. This is more than three-quarters of a mile in major diameter, with sides and floor strewn with ground-moraine, and still preserving traces of an original cirque-like character in spite of much dissection by small creeks and gullies. These converge to flow west through a narrow opening to join Geehi Creek, whose waters enter the Upper Murray some 40 miles down from the mouth of Leatherbarrel Creek.

The boulder-strewn floor of the gap in the western wall of the Cootapatamba valley slopes up very gently to the west and gives the impression of a little glaciated valley draining to the east, but Cootapatamba Creek maintains its westward course against this slope to the point where it tumbles down into the large dissected cirque.

Apart from its collinearity there is clear evidence that the tributary gorge of Leatherbarrel Creek is cut in a former continuation of Cootapatamba valley since, though the wall of the gorge descends steeply and evenly from Ramshead Range on the east, a distinct shoulder appears on the west, a remnant of the pre-rejuvenation valley, at about the level (*c.* 6,200 ft.) of the flat Cootapatamba valley, and evidently a former continuation of it.

The Cootapatamba valley is eroded approximately along a narrow belt of phyllite running N.N.E.–S.S.W. and dipping steeply to the east, bounded by hard acid gneissic granite on the west and the hard acid granite of the Ramshead Range on the east. This is the same phyllite belt in which are eroded farther north the collinear valley of an Upper Snowy tributary and the elongated Lake Albina; it narrows to a width of about 400 yards in the Cootapatamba valley and continues south along the left bank of the Leatherbarrel tributary. The collinearity of all the features mentioned is clearly due to glacier- and river-erosion in the belt of relatively soft rock.

The rejuvenated Leatherbarrel tributary is not heading back directly into the floor of Cootapatamba valley but cutting into its eastern bank, possibly along a specially weak band of phyllite; already it appears to have captured a small tributary, and the capture of the main stream is clearly only a matter of time.

To find an explanation for this curious condition of physiographic affairs we must hark back to the time of the second Pleistocene glaciation, when a glacier filled Cootapatamba valley and its continuation in a S.S.W. direction for an unknown but probably considerable distance. From the right a small tributary glacier joined it where the creek now breaks through its western wall, and at the back of this was a large cirque facing west and forming the head of a glacier-filled valley tributary to that of Geehi Creek. Backward ice-erosion of this latter cirque caused it to impinge on and eventually cut into the tributary valley. On the melting of the ice (which was accomplished first in the western cirque) the west-flowing creek captured bit by bit the headwaters of the little tributary till eventually it eroded back to the middle line of the main valley and captured its headwaters. Meanwhile, rejuvenation of Leatherbarrel Creek (consequent on the Kosciusko uplift), which had proceeded steadily

during the glaciation, continued thereafter till now it has reached to within a very short distance of where Cootapatamba Creek turns west. An alternative explanation would attribute the apparent capture to overflow through the gap from the glacial rock-basin formed in the floor of the Cootapatamba valley.

It is clear that Leatherbarrel Creek, which at present drops some 4,200 feet in about nine miles to reach the Murray, will continue vigorous headward erosion along the phyllite belt. Cootapatamba valley at the point of capture is still in virtually the same mature condition as when the ice melted, rejuvenation having proceeded at a slow rate against the gneissic foliation of the acid granite. In the process of time it will have recaptured the headwaters of Cootapatamba Creek, which thereafter will be gradually deepened back to the Main Divide at Rawson Pass. The Upper Cootapatamba–Leatherbarrel Creek will thus have become one again as in the days before the valley-glaciation, the water-gap in the western wall will have changed to an air-gap, and the disruption initiated by Pleistocene ice-erosion will have been redressed by rejuvenated river-erosion in the present cycle.

It must be very uncommon for a beheaded stream to recover its lost headwaters, as Leatherbarrel Creek is destined to do, because normally the victim has a lower gradient and a slower rate of erosion than the aggressor, and the handicap is accentuated by the diversion of the headwaters. In the present instance the pirate stream, Geehi Creek, actually had a longer course to the Murray and a lower average gradient, and was eroding against the grain of the granite, whereas Leatherbarrel Creek was carving its valley into softer rocks along their strike. It is therefore most probable that the capture of the Cootapatamba headwaters was the result primarily of ice-action, as suggested above, and not of normal river-erosion. Once the advantage conferred by ice-erosion disappeared Leatherbarrel Creek was rejuvenated much more rapidly than Cootapatamba Creek, and retribution will be fully accomplished when the pirate is beheaded by its erewhile victim.

(*b*) The two small tributaries of Cootapatamba Creek mentioned above which join it on the right bank show signs of derangement in their upper parts. On a shelf or bench fronting Mt. Kosciusko on the west and 700 feet below it a creek rises in a flat, somewhat swampy, moraine-filled col and meanders along a wide shallow valley through a drained bog in a southerly direction for about half a mile; it then turns sharply to the west, flows through a gap *c.* 50 feet high and 50 yards wide, tumbles down rather abruptly through about 100 feet in 50 yards, and flows with a gentle gradient through two intersecting shallow basins each about 300 yards across (indicated by curved broken lines in Fig. 1), breaching the low bounding ridge or spur between them. The more westerly basin, whose floor is 25 or 30 feet below that of the other, is alluviated, and across its silts the creek meanders to pierce its western wall, some 100 to 150 feet high, by a water-gap about 400 yards long and 50 yards wide at the base, thereafter making a rapid descent of more than 1,400 feet and flowing west to join Lower Cootapatamba Creek 1½ miles away. Southwards from the little basins the land rises gradually for about 600 yards through 70 feet to a col, bounded by ridges 150 to 250 feet high, which forms the head of the more westerly (C_2) of the two south-flowing tributaries of Upper Cootapatamba Creek.

Evidences of glaciation abound. The flat col in which the creek rises is moraine-strewn, its eastern wall shows signs of shorn spurs, and the long, narrow bog which it traverses clearly lies in an ice-scooped trough or basin. Beyond the point where the creek turns west the valley itself continues south to a moraine-strewn col hung up above the eastern basin. Morainic boulders pack the gut where the creek passes west, the sides and floor of the eastern basin and the water-gap by which the creek pierces the western wall, and moraine strews the floor of the valley south of the little basins, culminating in the col 600 yards south of the westerly one. Signs of glacial erosion are evident in the numerous shallow cols in the ridges, and in the smoothed faces of granite in the water-gaps and as scattered outcrops within the eastern basin. The silts in the western basin show some banding, though it is uncertain if this is fluvio-glacial.

The gorge into which the creek plunges below the western basin has a roughly basin-shaped appearance and may be a large cirque belonging to the valley-glacier stage now much dissected.

The probable history of the present drainage-scheme may be taken back to the pre-valley-glacier stage, when there may have been two parallel river-valleys rising west of Mt. Kosciusko and trending south into Cootapatamba valley—the ancestors of C_1 and C_2. During the valley-glacier stage both were gradually filled with the ice of

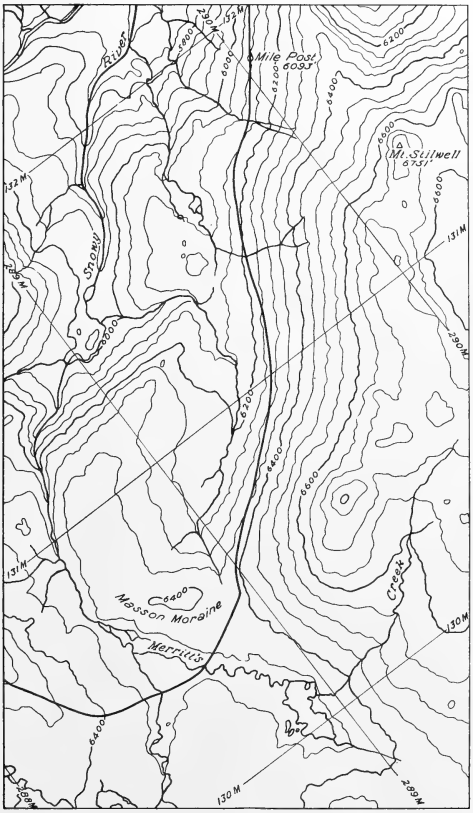

Fig. 2. A map of part of the Upper Snowy drainage system. The length of the side of a square on the grid represents one mile. North is towards the top left.

two glaciers, which eventually coalesced through the partial submergence of the ridge dividing them. At first both glaciers discharged into Cootapatamba valley, but later, through breaching of the ridge in two places, the better-nourished ice in the headward part of the eastern glacier was almost wholly diverted to join the western, which had its head in two shallow cirques. The ice accumulating near the head of this western valley spilled over a low part of its western wall into a large cirque at the head of a west-flowing tributary of the Lower Cootapatamba valley, and the path it took

eventually became a principal outlet. Mild over-deepening gave rise to the elongated basin at the head of the creek and to that in the more western cirque.

When the ice finally melted the eastern meridional stream following the path of the glacier assumed its present course, determining factors being the deposition of moraine in the col just below its right-angled bend and in the larger col at the head of C_2. Seasonal deposition of clays occurred in the over-deepened basins, followed by the formation of bogs in them. These have been drained and their characters modified through the erosion of meandering channels.

Thus it would seem that beheading of the two pre-glacial streams C_1 and C_2 and the formation of the apparent water-gaps at A and B were due primarily to erosion by valley-glaciers.

Diversion in the Upper Snowy System.

The most southerly headwaters of the Snowy River rise in the acute angle formed by the junction of the Main Dividing Range and the Ramshead Range. There are three principal streams, each of which after descending from the higher ground meanders over an alluviated flat. The two more westerly streams join about 500 yards south of the Summit Road, and the most easterly—Merritt's Creek—flows north-west to join the main stream some 200 yards north of the road. The flats are strewn with moraine blocks and are to some extent boggy and have the appearance of drained lakes, though boring with a soil-auger revealed no sign of varved structure in the clays. The basins are bounded by ridges of solid granite, partly moraine-covered. Based on the Kangaroo Range and running a little north of west, the Masson Moraine* bounds Merritt's Creek on the north-east. Heading on the northern flank of this moraine is a creek which may be called Masson Creek; this flows north-east in a valley with wide flare, separated from the Snowy River by a ridge about 150 feet high. About a mile down its valley the creek turns sharply left, flows through a gap 100 feet high in the bounding ridge, and descends about 120 feet in 500 yards to join the Snowy (Fig. 2). At the bend a small collinear tributary comes in from the north rising in a col, and on the other side of this valley-divide rises another small creek which joins the Snowy a mile farther down, descending gently and then steeply through some 400 feet in 1,100 yards by a veritable hanging valley. Glacial evidences are present everywhere. The three headwater basins have obviously been scooped out by glaciers, and numbers of large erratics are strewn over their floors. Looking up Masson Creek one observes the Masson Moraine, with boulders up to 20 feet long, stretching like a great wall more than 100 feet high across its head and continuing west as a veneer on the solid granite of the ridge separating Masson Creek from the Snowy right over to the river itself. The valley floor and sides of Masson Creek are also strewn with moraine boulders, and at one point the deposits of a tiny drained lake dammed by a little recessional moraine are seen.

It appears that prior to the valley-glaciation the valleys of Merritt's Creek and Masson Creek were continuous across the site of the present Masson Moraine and joined the Snowy about a mile north of the present mouth of Masson Creek. Later the headwater tracts of the Snowy and Merritt's Creek were much modified by glacier-ice, which was continuous across them both. One glacier descended the present Snowy valley and another occupied the Merritt-Masson valley at a higher level. With increasing refrigeration the ice overtopped the dividing ridge in places and eventually overflowed through a gap in this ridge, which in time became deepened to form the chief outlet, the attenuated remainder continuing on in the original valley to join the Snowy glacier farther north. On the retreat of the glaciers the ice-gap became the outlet for the thaw-waters, and part of the northerly continuation of the Masson Creek valley became obsequent while the remainder flowed north to the Snowy by the thalweg of the original tributary glacier.

* In what follows we assume that this moraine (first noted by Taylor *et al.* in 1925) is a true recessional or terminal moraine, as it appears to be, and not an accumulation of ground-moraine above a core of solid granite.

A subsequent halt by the retreating ice gave rise to the Masson Moraine, which stretched from the valley of Merritt's Creek across to that of the Snowy and formed a barrier that on the complete melting of the ice converted the headwater tracts into an expanse of lake-waters, by whose overflow it was eventually breached on its western side.

Thus the original Merritt-Masson Creek suffered diversion and mutilation at two points as the result of erosion and deposition by valley-glaciers.

Acknowledgements.

This paper records some of the research done under the auspices of the Joint Advisory Scientific Committee of the Linnean and Royal Zoological Societies of New South Wales. Grateful acknowledgement is made to the Snowy Mountains Authority for accommodation and transport, to the Kosciusko State Park Trust for transport, and to the Australian and New Zealand Association for the Advancement of Science for grants to cover the expenses of the field investigations. The maps are reproduced by kind permission from contour maps belonging to the Snowy Mountains Authority.

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AN ESTIPULODIC FORM OF *CHARA AUSTRALIS* R. BR. (= *PROTOCHARA AUSTRALIS* WOMS. AND OPHEL).

By MARY B. MACDONALD* and A. T. HOTCHKISS, Department of Botany, University of Sydney.

(Plates ix–x; six Text-figures.)

[Read 30th November, 1955.]

Synopsis.

Plants from New South Wales and Victoria intermediate in form between *Chara australis* and *Protochara australis* are described together with a report on chromosome number, culture methods and breeding experiments. In the taxonomic summary reasons are presented for combining *Protochara* with *Chara*.

In 1947, *Protochara* Woms. & Ophel, a new genus of the Characeae, was described from Australian material. This new genus was set up to include the two species *P. australis* Woms. & Ophel, and *P. inflata* (Filarszky & Allen, ex Fil.) Woms. & Ophel.

Protochara australis strongly resembles *Chara australis* R. Br. var. *australis* (= var. *nobilis* A. Br.) and seems to differ from the latter mainly in the usual absence of stipulodes and bract-cells. For various reasons, as given below, we find that *Protochara* cannot be retained as a distinct genus, and that *P. australis* and *P. inflata* should be transferred to the genus *Chara*.

HISTORY OF THE COLLECTIONS.

Several collections of the Characeae from Western Australia, South Australia, Victoria and New South Wales have been referred to the genus *Protochara*. The first of these, Burbidge, Sept., 1933, was referred (Filarszky, 1936) to the genus *Nitellopsis*, as *N. inflata* Fil. & Allen. Later, *N. inflata* was transferred (Womersley & Ophel, 1947) to the genus *Protochara*.

A second collection, Womersley A 5917 a, also from Western Australia, was referred by Womersley and Ophel (1947) to *Protochara* as *P. australis*, which was designated the type species of the genus. At the same time a collection of *P. australis* was made by G. G. Smith from the same locality. Subsequent attempts to collect material of *Protochara* in Western Australia have been unsuccessful, but recently an abundance of *P. inflata* has been found in South Australia.

Our own collections of *Protochara* have been made from one locality near Cooma, New South Wales (Hotchkiss 90, 91, and Macdonald 292, 293), and in one instance from the Brisbane Ranges, Victoria (Macdonald 320). Because of the absence of stipulodes and bract-cells, difficulty was found at first in identifying this material. The generic names *Tolypellopsis* and *Nitellopsis* were considered until finally *Protochara* was arrived at. Material was sent to H. B. S. Womersley, who kindly confirmed this latter identification. The habit of *Protochara australis* from Cooma, New South Wales, is shown in Plate ix, Figs. 1, 2.

ECOLOGY.

A study of what is known of the collection localities indicates that there may be some correlation between the type of habitat and the entities assigned to the genus *Protochara*. The common features in the various localities include shallow water and an intermittent water-supply in which the period of water may be of much shorter duration than the dry period, and probably prolonged periods of sunlight of high intensity. Table 1 summarizes observations made at the site at Cooma, New South Wales.

* Linnean Macleay Fellow in Botany.

TABLE 1.
Collection Data at Cooma, N.S.W.

Date.	Depth.	Notes.
December, 1952	90 cm.	Characeae not observed.
February, 1953	60 cm.	Characeae fruiting, collections made.
May, 1953	Nearly dry.	Characeae dying; collection of viable spores from the wet bottom mud.
January, 1954	Entirely dry.	Ground cracked open; collection of viable spores from dry bottom mud.
August, 1954	Entirely dry.	
January, 1955	Entirely dry.	Collection of viable spores from the dry bottom mud.

Other members of the Characeae also found growing at the Cooma site are *Chara muelleri* A. Br. and *Nitella gloeostachys* A. Br. A flourishing stand of *Nitella lhotskyi* A. Br. was grown subsequently from spores collected with the bottom mud. In the Western Australian site near Minginew, the species associated with *P. australis* were

TABLE 2.
Comparison between Cooma and Minginew Material and Camden Material of C. australis.

Character.	Cooma Field Material.	Cooma Culture Material.	Minginew Field Material (*fide* Womersley and Ophel).	*C. australis* var. *australis* Camden Field Material.	*C. australis* var. *australis* Camden Culture Material.
Internode diam. (mm.)	1–1·5	0·75–0·85	0·9–1·5	1–1·5	0·85
No. of branchlets (limits)	6–8	6–8	4–7	6 occ. 7	6 occ. 7
No. of segments in branchlets.. ..	3–4	3–4	3–4	3–4	3–4
Length of branchlets (cm.)	0·5–2	0·5–1	1·5–3	1–3 occ. up to 5	1–3 up to 5
Diam. of antheridium (μ)	1000–1250	1000–1250	800–1150	1000–1250	1000–1250
Length of oospore (μ)	650–750	650–750	490–560	725–800	700–800
No. of striae on oospore	5–6	5–6	5–6	5–6	5–6
Height of crown of oogonium (μ) ..	150	150–175	75	125	125
Diam. of crown at base (μ) ..	250–300	275–300	225	250	250
Length of stipulodes (μ)	375	375	Absent	250–300	250–350
Length of bracts (μ)	50–250	50–250	Absent	200–250	200–250
Length of bracteoles (μ)	175–450	175–500	Absent	200–250	200–250

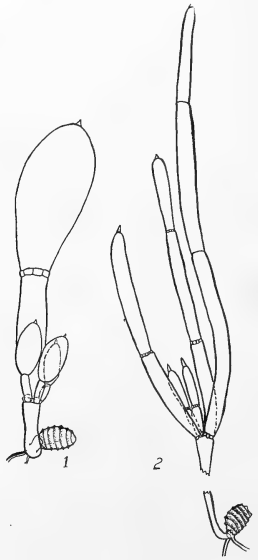
Lamprothamnium macropogon (A. Br.) Ophel and *Nitella gelatinosa* A. Br. This may indicate that the Cooma and Minginew plants have slightly different ecological preferences.

On the other hand, *Chara australis* var. *australis* growing near Parramatta (which may be the type locality) and elsewhere near Sydney, N.S.W., inhabits pools of slowly flowing streams and other permanent bodies of water. In these areas *Chara australis* is often associated with *Nitella cristata* A. Br. and *Chara gymnopitys* A. Br.

Morphology.

General.

Cultures of *Protochara* from Cooma and of *Chara australis* var. *australis* from Camden were set up for potential use in cell physiological studies. The two forms were noted to be very similar in habit. This is shown by the data given in Table 2, in which a comparison of characters generally used in species descriptions is made for *Protochara australis* from Cooma and Minginew and *Chara australis* from Camden.



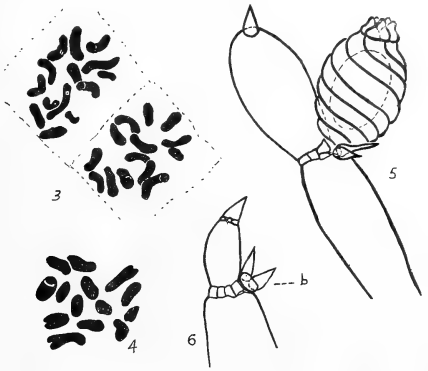
Text-fig. 1. *C. australis* subsp. *estipulodica* (= *Protochara australis*). Camera lucida drawing of young sporeling stage showing inflated protonemal appendage. *Ca.* ×10.

Text-fig. 2. *C. australis* subsp. *australis*. Camera lucida drawing of young sporeling stage showing protonemal appendage. *Ca.* ×10.

Stipulodes, Bracts and Bracteoles.

Occasional stipulodes, bracts and bracteoles were noted during routine examination of the cultures. The preserved field material from Cooma was re-examined carefully, and nearly every strand was found to have one or two stipulodes or bract-cells (Plate x, Figs. 1–3). Furthermore, the female plants from Cooma repeatedly showed 3–4 well-developed bracteoles closely appressed to the lower side of each oogonium so as to be practically invisible until the oogonium was detached (Plate x, Fig. 4; Text-figures 5, 6). No bracteoles were found under the antheridia of male plants, but a bract was often present at nodes bearing antheridia.

Portions comprising some 5–20 nodes each were selected at random from male and female plants of cultured and field material and were examined at a magnification of 40×. Each axial node was scored for the number of branchlets and stipulodes; each



Text-fig. 3. Mitosis, spermatogenous filament, *C. australis* subsp. *estipulodica* (= *Protochara australis*). Camera lucida drawing of metaphase showing 14 chromosomes. *Ca.* ×1750.

Text-fig. 4. Mitosis, spermatogenous filaments, *Chara australis* subsp. *australis*. Camera lucida drawing of metaphase showing 14 chromosomes. *Ca.* ×1750.

Text-fig. 5. *C. australis* subsp. *estipulodica* (= *Protochara australis*) from Cooma, New South Wales. Camera lucida drawing showing bracteoles subtending oogonium. *Ca.* ×20.

Text-fig. 6. *C. australis* subsp. *estipulodica* (= *Protochara australis*) from Cooma, New South Wales. Camera lucida drawing showing bracteoles; oogonium detached at *b*. *Ca.* ×20.

TABLE 3.

Frequency of Stipulodes and Bracts for Protochara australis *from Cooma Pond.*

	Cultivated Plants.		Preserved Field Material.	
	♀	♂	♀	♂
No. of different plants sampled	7	5	Indeterminate	Indeterminate
Total No. of filaments examined	7	14	4	4
Total No. of nodes counted	125	193	39	52
No. of filaments having, per 100 axial nodes:				
0 stipulodes	1	8	1	3
0– 5	0	1	0	1
5–10	1	2	1	0
10–15	2	1	1	0
15–20	3	2	0	0
20+	0	1	1	0
Actual No. of stipulodes present on the number of nodes counted	12 in 125	28 in 193	7 in 39	1 in 52
No. of plants having, per 100 branchlet nodes:				
0 bracts	4	5	1	2
0– 2	1	3	1	1
2– 5	2	1	1	0
5–10	0	2	1	1
10–20	0	2	0	0
20–30	0	2	0	0
30+	0	1	0	0
Actual No. of bracts present on the number of branchlet nodes counted	8 in 602	99 in 1092	12 in 364	19 in 165

branchlet-node for the number of bracts. It must be emphasized that these data are based on a limited number of observations as shown in the first three lines of Table 3. Consequently differences between the mean numbers of stipulodes of male and female plants need not be significant.

Cytology.

Entire whorls bearing young antheridia were detached and fixed in 3:1 acetic-alcohol for ½–6 hours. The antheridia were then dissected in a drop of aceto-orcein on a slide under a binocular microscope. The sperm filaments were teased well apart and a coverslip added. The preparation was then crushed out with strong pressure, heated slightly to clear the material and stick it to the slide, and sealed with wax. Subsequently, preparations were made permanent with Euparal.

Both *Protochara australis* from Cooma and *Chara australis* var. *australis* from Camden show 14 chromosomes (Plate ix, Figs. 3, 4; Text-figs. 3, 4) in the divisions of the spermatogenous filaments. This suggested at once that the two might be interfertile. The possession of cultures of *Chara australis* and *Protochara australis* offered a unique opportunity to study the relationship of these two entities by means of cross-breeding experiments.

Cultures.

Cultures of *Protochara australis* were raised by germinating spores contained in wet (1953) or dried-out (1954, 1955) mud from the floor of the Cooma pond. Portions of the mud were placed in crystal dishes and covered with tap-water. Germination at room temperature (about 18–20°C.) occurred sporadically in the cultures based on wet mud; in those based on the dried mud a burst of germination occurred in the fourth week from soaking with water and thereafter sporadically for about four months.

The young *Protochara australis* sporelings could be separated from other species present by their distinctive protonemal appendage (Text-figs. 1, 2). They were transplanted into 1500 ml. tall-form beakers with some of the Cooma soil, and placed in a constant-temperature room at 22–25°C., about 30 cm. beneath two 80-watt "daylight type" fluorescent tubes. It has been reported (Karling, 1925) that sex organs were produced in *Chara fragilis* when grown under long-day conditions. Consequently the cultures of young *Protochara* sporelings were placed under lights set for a 16-hour day. Under these conditions sex organs developed within 2–4 weeks from time of placing under the lights. Cultures of *Chara australis* were established by moving clumps of plants from the field to large jars in the laboratory and then transplanting portions to 1500 ml. beakers.

Breeding Experiments.

Since both *Chara australis* and *Protochara australis* are dioecious, controlled cross-breeding experiments were easily performed. *Protochara* sporelings were grown 3 or 4 per jar. When young sex organs were recognizable, the male and female plants were segregated in separate jars by transplanting or cutting out the unwanted sex.

Crossings were performed by placing the detached upper 4 or 5 nodes of a male plant with nearly mature antheridia in a jar containing a rooted female. It was observed that antheridia matured and burst in a regular sequence from whorl to whorl, usually one antheridium per day. This occurred in the detached piece just as in the entire, rooted male plant. The oogonia also mature in sequence from whorl to whorl as do the antheridia. An oogonium ready for fertilization consists of the grey, translucent egg-cell enveloped by the five spiral-cells which are orange in colour from the presence of carotinoid (P. Clark, unpublished data) pigments in the plastids.

If fertilization occurs, the wall of the oogonium and the inner walls of the spiral cells become impregnated with dark-coloured substances and become black. Nordstedt (1889) reported that suberin and silicic acid could be detected in the fruits of the Characeae. The oogonia of both *Chara australis* and *Protochara australis* darken within seven days after adding ripe antheridia to the cultures of female plants at 25°C. The ripened spore may be shed within 4–6 weeks after fertilization.

If fertilization does not occur, the egg-cell remains greyish in colour for about a week while the spiral cells gradually fade. Then the egg, rather abruptly, becomes white, and the oogonium falls off within a few days. In no case was a ripe spore observed to be formed in the absence of a male plant. To ensure that the sperms were viable in matings which gave no ripe spores, portions of the one male plant were mated with females of its own kind, as well as with the test female. In Table 4 are shown the crosses performed and the results.

TABLE 4.

Matings of Chara australis *var.* australis × Protochara australis.

Female Parent.	No. of Plants.	Male Parent.	No. of Plants.	Total No. of Matings.	Result.
Protochara australis.	16	*Chara australis.*	5	26	Ripe spores* developed normally.
Protochara australis.	10	*Protochara australis.*	6	10	Ripe spores developed normally.
Protochara australis.	2 and portions of others.	Control with no male plant.	—	—	No ripe spores developed.
Chara australis.	10†	*Protochara australis.*	4	7	No ripe spores developed.
Chara australis.	10†	*Chara australis.*	2	6	Ripe spores developed normally.
Chara australis.	10†	Control with no male plants.	—	—	No ripe spores developed.

* In one case only this cross failed to produce ripe spores. This could have been due to immaturity of the oogonia at time of mating.

† The same clump of at least 10 female plants of *Chara australis* was used for this series of three experiments.

In Table 4 it is shown that females of *Protochara australis* (from Cooma) can be fertilized by males of *Chara australis.* On the contrary, females of *Chara australis* cannot be fertilized by the males of *Protochara.* In other words, the sperm of *Protochara* are incompatible with the eggs of *Chara.* The basis of this incompatibility is at present unknown.

As yet, none of the spores produced by crossing *Protochara* × *Chara* have been germinated. The spores of Characeae in general seem to show well-developed dormancy mechanisms. So far, it has not been possible to germinate the spores of any species at will. Spores of Characeae which germinated after soaking dried soil from the Cooma pond were two years old and probably passed through several periods of alternating brief wet and long dry conditions during that time (see Table 1). Some such treatment may be necessary to break the dormancy of *Protochara* spores. Although it is not yet known for certain that spores produced from the *Protochara* × *Chara* cross will germinate, the non-reciprocal fertility by itself is sufficient to indicate a rather close relationship between the estipulodic and stipulodic plants.

Discussion and Conclusions.

It has been suggested (Womersley and Ophel, 1947) that the absence of stipulodes, bract-cells and bracteoles may be regarded as a primitive condition in the Chareae. The partially stipulodic, bracteate and bracteolate condition of the Cooma plants suggests that the absence of these appendages in the plants from Western Australia is the result of loss through a gradual reduction series, and that the primitive condition in the Chareae is for stipulodes, bract-cells and bracteoles to be present. These appendages are present in an overwhelming number of species in the Chareae, although occasionally

rudimentary as in *Chara fragilis*. The status of any genus in the Chareae (such as *Nitellopsis* Hy.) dependent on the absence of appendages is called into question.

The two genera *Chara* and *Protochara* are morphologically very similar. This is particularly true when a comparison is made between the type species of *Protochara* (*P. australis*) and the ecorticate *Chara australis* subsp. *australis*; the absence of stipulodes and bract-cells in the former being the principal morphological distinction between the two. The finding of a series of plants which have scattered stipulodes and bracts, together with the evidence from cytology and breeding presented here, suggests that a complete lack of stipulodes and bract-cells in an occasional plant or population of plants is not to be regarded as a distinction of fundamental taxonomic importance. For all these reasons we propose to unite the genus *Protochara* with *Chara*.

With the merging of the two genera some disposition must be made for the two species of *Protochara*. Because the estipulodic plants referred to *Protochara australis* agree in general morphology and chromosome number, and have been shown to be partially interfertile with *Chara australis*, it seems best to treat them as a new subspecies of *Chara australis*. This treatment has the advantage of showing a close degree of relationship between the stipulodic and estipulodic plants while at the same time indicating the barrier to complete crossing and the morphological differences between them.

Although *Protochara inflata* has never been placed in *Chara* there seems to be little reason for excluding it from that genus. However, distinctions based on a general lack of appendages and perhaps also on the relative position of gametangia should be considered. Because *P. inflata* lacks stipulodes especially, it might be allowed to revert to *Nitellopsis*. But as Womersley and Ophel point out, the type species of *Nitellopsis* is characterized by the presence of long bracts also absent in *P. inflata*, the use of this character presents difficulties. A second species of *Nitellopsis* described by Zaneveld (1940) from very fragmentary material has rudimentary stipulodes as well as long bracts. From this it would appear that the presence (or absence) of these appendages in the Chareae is so variable that they are of taxonomic use only at the subgeneric level. (For the synonymy of *Nitellopsis* species, see Wood, 1952.) A distinction based on the relative position of gametangia is hardly applicable here because both recognized species of *Nitellopsis* are dioecious, while *P. inflata* is monoecious. Furthermore, the figure of *P. inflata* reproduced by Womersley and Ophel from Filarszky's drawing of it as *Nitellopsis* shows the relative position of the gametangia to be variable in this species. It would seem inadvisable to assign a species to such a doubtful genus without strong reasons for doing so. *Protochara inflata* is best treated by transferring to *Chara* as a new combination.

Taxonomic Summary.

Zaneveld (1940) reviewed *Chara australis* R. Br. and retained the three varieties described by A. Braun (1882), var. *nobilis*, var. *lucida*, and var. *vieillardii*, as well as a fourth, var. *plebeja*, first described as a separate species. (See Table 5.) Robert Brown (1810) did not designate a type, but as Zaneveld points out that var. *nobilis* is identical with R. Brown's type specimen for *Chara australis*, this variety may be taken as the typical element and as such should be designated var. *australis*. Zaneveld emphasizes that Kuetzing's (1857) remark on specimens of Mueller and Sonder, "Bracteen . . . fehlen gänzlich", is in error, as he, Zanefeld, has observed the bracts on them. There seems little doubt that the typical element of *Chara australis* does possess appendages.

The varieties distinguished by Braun, and maintained by Zaneveld, may be forms due partly to plastic modification under various environmental conditions. Some evidence for this is found in material from near Camden, N.S.W., which in the field habitat grows with the form of large, stout var. *australis*, but when transplanted to glass jars in the laboratory assumes the dimensions of var. *lucida*. Pending more detailed evidence we propose to let these varieties stand as members of the subspecies *australis*. The genus *Chara* is emended to include *Protochara*.

Chara Vaill. ex L.

Genus *Chara* Vaillant in *Mem. Acad. Roy. Sci. Paris*, 1719, p. 17; Linnaeus, *Gen. Plant.* ed. 5, 1754, p. 491. (For a detailed citation of references and synonymy see Zaneveld, 1940.)

Emended description (modified from Zaneveld, 1940): *Stem* and *branchlets* corticate or ecorticate. *Stipulodes* usually present, sometimes rudimentary or almost entirely suppressed. *Branchlets* consisting of 3–14 articulations. *Bract-cells* present or absent,

Table 5.

Comparison of Varieties of Chara australis *R.Br. with* Protochara australis *Wom. & Oph. (taken from Zaneveld and Womersley and Ophel).*

Sub-species.	*australis.*			*estipulodica.*
Varieties / Characters.	*australis* (=*nobilis*).	*lucida.*	*vieillardii.*	(*P. australis* from Minginew).
Habit	Stout to robust, inflated.	Rather stout, not inflated.	Fairly robust, not inflated.	Stout, inflated.
Appearance of herbarium specimens	Not glossy.	Extremely glossy.	Not glossy.	? Not glossy.
Stem diam. in mm.	1–3·5	0·25–0·75	0·45–1·5	0·9–1·5
Internodes compared to branchlets	0·5–2 times as long.	0·5 as long.	Same length.	1–2 times as long.
No. of branchlets	3–6	6	6–8	4–7
Length of branchlets in cm.	2–3	0·6–1·5	1·5–4·5	1·5–3
No. of segments	3–5	5	4–5	3–4
Diam. of antheridium in μ	800–1250	550–960	750–1250	800–1150
Length of oospore in μ	660–730	550–660	712–756	490–560
Height of crown cells in μ	70–80	90	130	75
Base of crown in μ	140–200	160	140	225
Length of stipulodes and bract cells in μ	f. *stuartiana* 300 f. *typica* 180	f. *typica* –f. *typica* 130 f. *tenerior*–f. *vitiensis* 250 f. *simplicissima* 90 or absent.		Absent.

when present 1–7, the posterior ones frequently reduced or lacking. *Bracteoles* present or absent, when present usually 2. Male and female *gametangia* in the monoecious species arising from the same peripheral cell of the branchlet-node, taking the place of a bract-cell. *Antheridium* produced below the oogonium.

1. Chara australis R. Brown, *Prodr. Fl. Nov. Holl.*, 1, 1810: 346; A. Braun in *Linnaea*, 17, 1843: 117. *Nitella stuartiana* Kuetz., *Tab. Phyc.*, 7, 1857: 11. *Tolypellopsis simplicissima* Filarszky in *Arch. f. Hydrobiol.*, 1934, Suppl. Bd. 12, Trop. Binnengew. Bd. 4: 716. *Protochara australis* Woms. and Oph. in *Trans. Roy. Soc. S. Aust.*, 71: 311.

Emended description (modified from Zaneveld, 1940):

Plant dioecious, bright green, up to 35 cm. high, usually not encrusted, or with slight annular incrustation. *Stem* very stout to rather slender. Internodes 0·5–2 or more times as long as the branchlets. *Cortex* and *spine-cells* completely absent. *Stipulodes* present (in subspecies *australis*) or rudimentary or absent (subspecies

estipulodica), if present up to *c.* 375μ long, about 80μ wide at the base, single or in pairs, but always alternating with the branchlets. *Branchlets* 3–8 in a whorl, 0·5–5 cm. long, consisting of 3–5, sometimes very swollen, articulations, ultimate articulation very short, frequently conical, acute, somewhat curved, rarely obtuse (var. *plebeja*), often ringed at the base by peripheral nodal cells, but some not. *Bract-cells* and *bracteoles* present or absent (if present up to 6 in number, 130–300μ long, 20–50μ wide at base), but frequently lacking at the base of the conical ultimate cell. Male and female *gametangia* produced in clusters of 1–7 at the base of the whorls, and 1–4(5) at the nodes of the branchlets (except the ultimate one). *Antheridia* when fresh dark orange, 660–1250μ in diameter. Oogonia 760–1000μ long (including corona), 530–780μ wide. *Spiral cells* showing (6) 7–9 broad convolutions; coronula 70–150μ high, 140–250μ broad at the base, individual crown cells blunt at apex, straight or slightly divergent, in a single row of five cells. Oospores black, 490–800μ long, 310–510μ wide, with 4–8 ridges.

Subsp. AUSTRALIS.

var. *australis*.—var. *nobilis* A. Braun in *Abh. Kön. Akad. Wiss. Berlin*, 1882: 105; Zaneveld in *Blumea*, 4, 1940: 124.

var. *lucida* A. Braun in *Abh. Kön. Akad. Wiss. Berlin*, 1882: 106; Zaneveld in *Blumea*, 4, 1940: 126.

var. *Vieillardii* A. Braun in *Abh. Kön. Akad. Wiss. Berlin*, 1882: 106; Zaneveld in *Blumea*, 4, 1940: 127, *pro parte* (incl. forma *typica* and forma *vitiensis* only).

var. *plebeja* A. Braun in *Abh. Kön. Akad. Wiss. Berlin*, 1882: 107, Pl. 7, f. 196; Zaneveld in *Blumea*, 4, 1940: 130.

Subsp. ESTIPULODICA, subsp. nov.—*Protochara australis* Womersley and Ophel in *Trans. Roy. Soc. S. Aust.*, 71, 1947: 311. This subspecies is based on Womersley and Ophel's type for *Protochara australis* No. A 5, 917a.

Distribution: Western Australia, Victoria, New South Wales.

Western Australia: Swampy areas of shallow water (10–40 cm. deep) on top of the peneplain of the "breakaway" country between Minginew (about 15 miles from Minginew) and the Irwin River coal seam, S.E. of Geraldton, H. B. S. Womersley A 5917b (ADEL–U), Aug. 28, 1947 (*Type locality*); Moora, J. Burton Cleland (HERB. N.S.W.), Sept., 1900.

Victoria: Durdiwarrah Reservoir, Brisbane Ranges, 60 miles N.W. of Melbourne, M. B. Macdonald 320 (SYD–U), Aug. 20, 1955.

New South Wales: Temporary, shallow, roadside pond between Cooma (about 11 miles from Cooma) and Jindabyne, A. T. Hotchkiss 90, 91 (SYD–U), Jan., 1953.

Cultivation: New South Wales: Cultures raised from spores collected from same location as in Hotchkiss 90, 91; M. B. Macdonald 292, 293 (SYD–U), Jan., 1954, Jan., 1955.

NOTE: Forma *simplicissima* (Filarszky) Zaneveld is referred to by Zaneveld (1940) as having "stipulodes and bract-cells—hardly developed or rudimentary", and he specifically confirms Filarszky's diagnosis that these appendages are absent. However, he does not agree with Filarszky's classification of the plant as *Nitellopsis simplicissima*; he places it as a form of *Chara australis*. Because it lacks stipulodes and bracts it probably should be placed in subsp. *estipulodica*. It differs somewhat in size from the type of subsp. *estipulodica*.

2. CHARA INFLATA (Fil. and Allen ex Fil.), comb. nov.—*Nitellopsis inflata* Fil. and Allen ex Fil. in *Matematikai és Természettudományi Értesitöje*, 55, 1937: 476-495. *Protochara inflata* Woms. and Oph. in *Trans. Roy. Soc. S. Aust.*, 71, 1947: 314.

Distribution: Western Australia, South Australia.

Western Australia: Brackish, shallow water in Lake Parkeyerring, about five miles south of Wagin, N. T. Burbidge, Sept., 1933. *Type* (not seen).

South Australia: Near edge of Thornden Park reservoir, H. B. S. Womersley A 12988p (ADEL–U), March 16, 1950.

Key to the Tribe Chareae.

Section Haplostephanae.
Subsection Ecorticatae.

1. Stipulodes alternating with base of branchlets (*alternantes*).
2. Dioecious.
3. Base of whorls sterile, gametangia solitary ..... *C. fulgens* Filarszky.
3x. Base of whorls fertile, gametangia aggregated.
4. Bract-cells small or lacking, only microscopically visible ..... *C. australis* R. Br.
5. Bracts, bracteoles and stipulodes all regularly present at each whorl . subsp. *australis*.
5x. Bracts and stipulodes absent or only one or two present at an occasional node .... subsp. *estipulodica*.
4x. Bract-cells large and visible to the naked eye ..... *C. Wallichii* A. Br.
2x. Monoecious.
6. Base of whorls fertile.
7. Bracts and stipulodes absent ..... *C. inflata* (Filarszky) Macd. & Hotch.
7x. Bracts and stipulodes present ..... *C. corallina* Willdenow.
6x. Base of whorls sterile.
8. Gametangia aggregated, branchlets terminated by a crown-like group of bracts .... *C. Braunii* Gmelin.
8x. Gametangia solitary, branchlet-tips not crown-like ..... *C. nuda* Pal.
1x. Stipulodes opposite base of branchlets (*oppositae*).
9. Oogonia, but not antheridia at base of branchlet whorls; bract-cells at ultimate node of branchlets well developed. Monoecious ..... *C. succincta* A. Br.
9x. Neither oogonia nor antheridia at the base of branchlet-whorls; bract-cells lacking at ultimate node of branchlets. Monoecious ..... *C. pashanii* Dixit.

SUMMARY.

Plants from near Cooma, New South Wales, have been identified as *Protochara australis*. These plants, although nearly free of appendages, occasionally show definite stipulodes, bracts and bracteoles. Both the Cooma plants and *Chara australis* from near Sydney, New South Wales, have 14 chromosomes. Breeding experiments with representatives from these two populations show that they are non-reciprocally interfertile. It is concluded that *Protochara* Woms. and Ophel is not generically distinct from *Chara*. *Protochara australis* Woms. and Ophel is transferred to *Chara* as *Chara australis* subsp. *estipulodica* subsp. nov. *Protochara inflata* (Fil. and Allen ex Fil.) Woms. and Ophel is transferred to *Chara* as a new combination.

Acknowledgements.

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EXPLANATION OF PLATES IX-X.

Plate ix.

1. Habit of male plant of *C. australis* subsp. *estipulodica* (= *Protochara australis*) cultured from Cooma, N.S.W. *Ca.* × 1½.

2. Habit of female plant of *C. australis* subsp. *estipulodica* (= *Protochara australis*) cultured from Cooma, N.S.W. *Ca.* × 1½.

3. Mitosis in spermatogenous filament *C. australis* subsp. *estipulodica* (= *Protochara australis*). Photograph of metaphase showing the same 14 chromosomes drawn in Text-fig. 3. *Ca.* × 1800.

4. Mitosis in spermatogenous filament, *Chara australis* subsp. *australis*. Photograph of metaphase showing the same 14 chromosomes drawn in Text-fig. 4. *Ca.* × 1800.

Plate x.

1. Plant of *C. australis* subsp. *estipulodica* (= *Protochara australis*); cultured material from Cooma. Photograph showing two stipulodes (the only ones present) and a solitary bract-cell. *Ca.* × 48.

2. Plant of *Chara australis* subsp. *australis*; cultured material. Photograph showing stipulodes and bract-cells. *Ca.* × 48.

3. Branchlet of *C. australis* subsp. *estipulodica* (= *Protochara australis*); cultured material from Cooma. Photograph showing antheridial stalk cell and bract. *Ca.* × 30.

4. Branchlet of *C. australis* subsp. *estipulodica* (= *Protochara australis*); cultured material from Cooma. Photograph showing two oogonia with bracteoles at base. *Ca.* × 30.

A NEW CHROMOSOME FORM OF *CASUARINA SUBEROSA*.

By B. Barlow, Botany Department, University of Sydney.

(Nine Text-figures.)

[Read 30th November, 1955.]

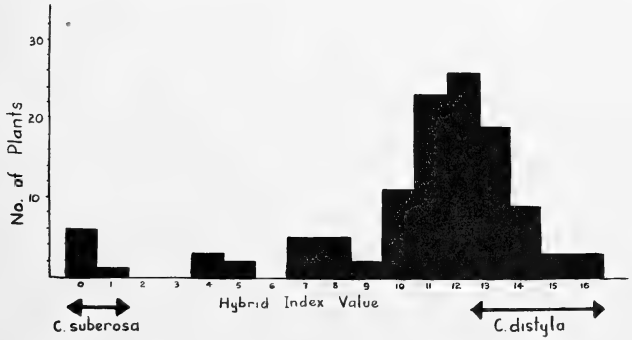
Synopsis.

Apparent hybridization between *Casuarina suberosa* and *C. distyla* is described, and the possible nature of the hybridization is discussed. A new chromosome form is reported for *C. suberosa*, having a somatic chromosome number of 22.

Introduction.

One of the first taxonomic classifications of the species of the genus *Casuarina* was published by Loew in 1865. He divided some twenty-four species into six sections on the morphological characters of the phyllichnia.* *Casuarina suberosa* and *C. distyla* were both included in the fifth of these sections. In all subsequent classifications the two species have been grouped together, and on morphological grounds they are considered to be closely related.

The two species have been found to differ in their chromosome numbers (Purcell, unpub.). *C. distyla* has 2n = 22 over a large part of its range (including the Sydney district). In some localities it has been found to be tetraploid; 2n = 44. The same author reported that in Tasmania *C. suberosa* has a diploid number of 48. Determinations by the writer on seeds collected from Manly, near Sydney, confirmed Purcell's determinations (Text-figs. 2, 3).



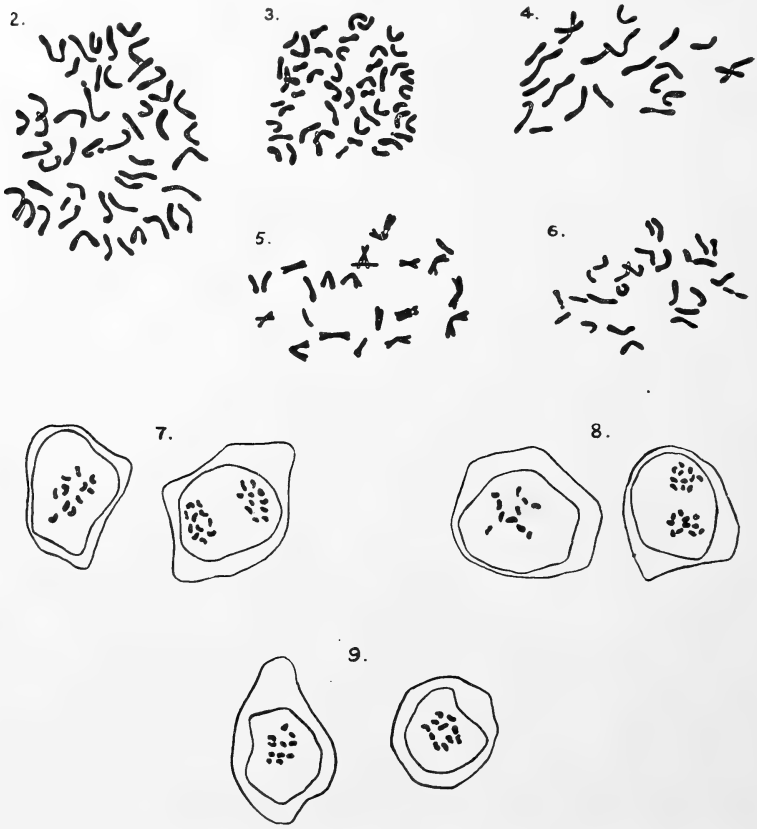
Text-fig. 1. Hybrid index of general population sample, Castle Cove.

The close relationship between the species is supported by the apparent occurrence of interspecific hybridization. In particular, hybridization between the two species was reported at Castle Cove, near Sydney. A cytological study of this population was made, with the aims, firstly, of confirming the occurrence of hybridization, and secondly, of studying the cytological relationships between the two species.

* The phyllichnia are ridges on the young stems of *Casuarina*, and are considered to be leaves, which arise in whorls at each node, are fused along the succeeding internode, and become free at the next node, where they terminate in teeth.

Morphological Studies and Field Observations.

The morphological variation in a population sample from Castle Cove, when compared with that in pure stands of *C. suberosa* and *C. distyla*, shows that in this locality a large range of intermediate types exists. These intermediates do not occur in pure stands of either species, and are presumptively of hybrid origin.



Text-figs. 2-9. These illustrations are not at a constant magnification. Fig. 2, *C. suberosa*, Manly. Metaphase of mitosis in seedling root-tip. 2n = 48. Fig. 3, *C. suberosa*, Manly. Metaphase of mitosis in foliage bud. 2n = 48. Figs. 4, 5, 6, progeny of intermediate forms, Castle Cove. Mitosis in seedling root-tips. Fig. 4, late prophase, 22 chromosomes. Fig. 5, metaphase, 22 chromosomes. Fig. 6, late anaphase, 25 chromosomes. Figs. 7, 8, pollen mother cell meiosis in intermediate plants, Castle Cove. 2n = 22. Fig. 9, *C. suberosa*, Castle Cove. Pollen mother cell meiosis. 2n = 22.

There are a number of diagnostic characters by which the two species can be distinguished. Those which were used for morphological study are:

C. suberosa: Cones truncate, cone valves prominent and angular, dorsal protuberances angular, branchlets slender.

C. distyla: Cones tapering at the apex, cone valves smooth, dorsal protuberances smooth, branchlets robust.

It was found that in all of these characters a complete range of intermediate types exists at Castle Cove. The expression of each of the four characters was noted in each plant sampled, and each plant was then assessed a total character value, following Anderson's Hybrid Index method* (Anderson, 1939).

The results of this analysis for the mixed population are given in the histogram (Text-fig. 1), in which the ranges of variation of the pure species are also indicated.

Most of the intermediate types resemble *C. distyla* more than *C. suberosa*, and they outnumber plants which, on morphological grounds, can be considered to be one or other parent species. Following any original hybridization, most of the plants of succeeding generations would be backcrosses, as the parent species would at first outnumber the hybrids. Most of these backcrosses would be with *C. distyla*, which is the more abundant parent. Conditions should permit an introgression of *C. suberosa* genes into *C. distyla*.

The hybrids only occur in abundance in a disused quarry, along the edges of a track, and in other disturbed sites. This would indicate that the F_1 hybrids are only able to survive in places which have suffered from human disturbance, with a consequent temporary reduction in selection pressure. The F_1 hybrids may therefore be inferior to either parent species, and unable to survive under natural conditions. It may well be that man, in clearing the area and allowing F_1 plants to survive, has paved the way for introgression and the breakdown of the natural isolation barriers between the two species.

Cytological Studies.

Since the putative hybrids set abundant seed, and male plants produce well-developed anthers, these plants have a high fertility. If *C. suberosa* has $2n = 48$ and *C. distyla* has $2n = 22$, this high fertility is unexpected, for an F_1 hybrid, with 35 chromosomes, would show abnormal behaviour at meiosis, and low fertility. Depending on the chromosome complements of the viable embryo sacs and pollen grains, F_2 and backcross plants could have chromosome numbers varying between 22 and 48.

Seeds were collected from a number of the putative hybrids. The chromosome number of the great majority of the seedlings germinated was determined to be 22, there being a few exceptional seedlings having up to 28 chromosomes (Text-figs. 4, 5, 6). These numbers are lower and more uniform than expected.

Meiotic divisions in the anthers of fifteen hybrids were observed. At first metaphase there were constantly eleven bivalents and no univalents (Text-figs. 7, 8). The meiotic divisions were quite regular, resulting in the production of good microspore tetrads. Again the chromosome numbers were lower, and the divisions more regular, than was expected. Some doubt arose as to whether these plants are indeed hybrids, or alternatively, whether this local population of *C. suberosa* does in fact have a chromosome number as high as 48.

Mitosis in seedling progenies of female trees, and also meiosis in the anthers of male trees (Text-fig. 9) of pure *C. suberosa* type were examined. In all cases the diploid number was found to be 22. The populations at Manly and Castle Cove show an aneuploid difference in their chromosome numbers. These two localities are only four miles apart.

The occurrence of a form of *C. suberosa* with 22 chromosomes conforms with the inferred close relationship between this species and *C. distyla*, and in part explains the high fertility of the apparent hybrids. The problem of the origin and relationships of the two chromosome forms within the species is being investigated.

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* The scales used were as follows:

Branchlet diameter less than 0·028", 0; more than 0·056", 5.
Cone valves very prominent, 0; smooth, 5.
Dorsal protuberances angular, 0; smooth, 3.
Cones truncate, 0; tapering, 4.

SUMMARY.

1. The chromosome number of *C. suberosa* has previously been determined to be 2n = 48.

2. At Castle Cove the somatic number of this species is shown to be 2n = 22.

3. This form has hybridized with *C. distyla*, which also has 2n = 22.

4. Hybridization is probably a result of human disturbance of the plants' natural habitat, and is being followed by introgression.

5. There is no measurable loss of fertility in the hybrids.

Acknowledgements.

I wish to thank Mr. S. Smith-White, Botany Department, University of Sydney, for many helpful discussions and much advice. I am also indebted to Mr. L. A. S. Johnson, of the National Herbarium, Sydney, who reported the presence of plants intermediate between the two species, and who showed me the site at Castle Cove.

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THE AUSTRALASIAN DIPTERA OF J. R. MALLOCH.*

By David J. Lee,[1] Mabel Crust[2] and Curtis W. Sabrosky.[3]

(With One Portrait, Plate xi.)

[Read 30th November, 1955.]

An index to the Diptera from the Australasian Region dealt with by J. R. Malloch, comprising lists of families, groups, genera and species with bibliographical references and present location of the type and other named material and a bibliography of those papers by J. R. Malloch which concern the Australasian Region.

1. Introduction and Acknowledgements.

The present task was conceived by one of us (D.J.L.) because of the need for stabilization of the important type collections housed in the School of Public Health and Tropical Medicine. It was inevitable that the exigencies of the past war should have occasioned some degree of neglect in these collections, and with changes of staff in a small department it became necessary to establish the *status quo* of the collections under its care.

This could have been done as a purely domestic matter, but, because of the outstanding significance and the great extent of the contribution made by J. R. Malloch to our knowledge of the Diptera of Australia and the Pacific, it was decided to extend this project to the point of providing a basic document of reference to the work of J. R. Malloch on Australasian Diptera.

For the attainment of our objectives Miss M. Crust was appointed to devote her attention to producing a bibliography of pertinent literature and lists of species and higher groupings, dealt with by J. R. Malloch. This formed the basis of the present work and she was then able to give her attention to the rearrangement and listing of all the material in the collection of this School described or otherwise dealt with by Malloch. This was no mean task and constituted an arduous part of the total labour involved and was almost exclusively accomplished by Miss Crust.

It was at this stage that the co-operation of other organizations was sought. We felt that having set our own house in order we could legitimately impose on the time of entomologists in institutions elsewhere in Australia and overseas to find the extent to which Malloch type material was represented in these places. In all cases co-operation was most readily forthcoming and due acknowledgement is made below. In this way a body of information was gradually built up on the disposition of Malloch type material, leaving towards the end a residue of 200 species, the whereabouts of whose types became problematical. At this stage the literature had to be checked again and approaches made to a number of other institutions which were reputed to hold small numbers of the types in question, until gradually the number of missing types was reduced to little more than 50.

These latter stages have involved the entry, in the previously prepared master list, of all information coming in from outside sources. The reliability of the master list has been cross-checked by the submission of this outside information, and since less

* The cost of publication of this paper was borne by the School of Public Health and Tropical Medicine, University of Sydney.

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[3] Insect Identification and Parasite Introduction Section, Agricultural Research Service, United States Department of Agriculture, Washington, D.C.

than a dozen species have been added to the list, this leads us to hope that it has attained a reasonably high order of accuracy.

It is often true that the complexities of a problem remain undisclosed until it is partially solved. In the present case we were aware of difficulties in working with Malloch material, but we had no conception of the very considerable difficulties inherent in the acquisition of Malloch's private collection by the United States National Museum. Indeed, our lists would never have approached completion, except for our own domestic problem, were we not able to have indirect access to this important collection. This indirect access has been provided by Curtis W. Sabrosky, of the staff of the United States Department of Agriculture, Agricultural Research Service, who has been in every sense a collaborator in the present task. His contribution to the final completion of these lists has been a very considerable one which has been all the more valuable because of his wide knowledge and critical approach to the many little problems involved. We are indeed most deeply indebted to the ever-willing assistance of Mr. Sabrosky. Other members of the same service who have also assisted in their particular fields are Dr. Alan Stone and Dr. Willis W. Wirth.

Outside Australia the next most important collection has been that of the British Museum (Natural History) and we are indebted to Mr. H. Oldroyd for listing and checking the fairly considerable holding of Malloch type material there. Dr. E. H. Bryan, Jr., of the Bernice P. Bishop Museum, provided us with all details of relevant material lodged there in a form which considerably lightened our own work.

Elsewhere outside Australia, Dr. F. Peus, of the Zoologisches Museum, Berlin, and Dr. H. Sachtleben, of the Deutsches Entomologisches Institut, have promptly supplied us with required information. We are also indebted to the Directors of the Musée Royale d'Histoire Naturelle de Belgique, the Rijksmuseum van Natuurlijke Historie, Leiden, the Hungarian Museum of Natural History, the Vienna Natural History Museum and the Zoological Museum, Hamburg, for information concerning the small holdings of Malloch material in these places.

Of most importance in Australia, apart from this School, have been the collections of the Division of Entomology, C.S.I.R.O., and of the Australian Museum. Dr. S. J. Paramonov and Mr. T. G. Campbell, of the former institution, have been most co-operative at all times, and for the latter Mr. A. Musgrave has been most helpful.

Mr. H. Womersley, of the South Australian Museum, and Mr. C. E. Chadwick and Mr. E. H. Zeck, of the New South Wales Department of Agriculture, have provided us with information concerning their respective institutions.

In New Zealand we are indebted to both Dr. D. Miller and Mr. A. W. Parrott, of the Cawthron Institute, for information concerning types held in both the Cawthron and the Canterbury Museum.

For details concerning Malloch's career we are indebted to Dr. W. V. King, Dr. W. L. McAtee and officers of the United States Fish and Wildlife Service. To Malloch himself we are grateful for the portrait reproduced herein.

Finally the unenviable job of typing this entire document twice fell to the lot of Miss C. Mullen, of this School, and we are most grateful for the care and patience she devoted to it.

It is appropriate, since Malloch published so many of his papers (45 papers totalling over 850 pages) in the PROCEEDINGS OF THE LINNEAN SOCIETY OF NEW SOUTH WALES, that this catalogue should be presented in this journal.

(D.J.L.)

2. J. R. MALLOCH.

John Russell Malloch is now living in retirement in Florida, having pursued a very active career in systematic entomology over a long period of years.

His birthplace was Milton of Campsie, Stirlingshire, Scotland, and the date, 16th November, 1875.

His early interest in entomology is evidenced by a number of papers appearing in journals such as the *Scottish Naturalist* following his graduation as Bachelor of Arts of the University of Glasgow in 1897.

In 1909 Malloch went to the U.S.A. and for a few years he travelled and worked in various jobs, including pattern designing in a silk works in New Jersey.

In 1912-13 he obtained a position as scientific assistant in the U.S. Bureau of Entomology; later he worked on insects at the Philadelphia Academy of Natural Science until he joined the State Natural History Survey of Illinois, where he remained until 1921.

His work with the U.S. Biological Survey (now Fish and Wildlife Service, Department of the Interior) commenced in June, 1921, when he was appointed Technical Assistant. Two months later he became Assistant Biologist, and in 1924 Associate Biologist, and was later promoted to Biologist in 1929, a position he held until the end of 1934, when he retired. He rejoined this department for a little over two and a half years in 1936-1938, when his official activities ceased, although his research activities continued for at least the next four years.

Malloch's early interests in entomology appear to have been in lepidopterous life histories, although his first descriptions of new species were of Hymenoptera. He also published on Hemiptera, but his long-continued interest has been in the Diptera, a group in which his studies embraced many families.

His work in the State Natural History Survey of Illinois culminated in the appearance of his important general work, "A Preliminary Classification of Diptera, Exclusive of Pupipara, based upon Larval and Pupal Characters, with Keys to Imagines in Certain Families", appearing in the *Bulletin of the Illinois State Laboratory of Natural History*, Vol. XII, article III, 1917, pp. 161-407.

From this period on his work has been exclusively on Diptera, but was far from confined to the fauna of the American continent. Important contributions were made to our knowledge of certain families on a global basis, but regionally his work extended to South America, the Pacific, Australasia, Malaya and Africa.

He has been, unquestionably, one of the most prolific Dipterists and it would now be difficult to assess the total number of species of which he is the author.

In the Australasian region we know that he described well over 1000 new species and reviewed more than twice as many more. This has been done in approximately 140 papers covering a range of 37 families of Diptera varying from the Bibionidae to the Tachinidae. In this region he has made important contributions to our knowledge of the Muscidae, Calliphoridae and Tachinidae, but even more important are his studies on the various families of Acalyptrate Muscoidea.

Most of Malloch's contributions to Australasian entomology came within the period 1920-1940, and in many of the groups he dealt with he was the sole worker.

His work is frequently basic and in many groups remains the latest authoritative work in Australian literature. Indeed, it is only in very recent years that there has been any attempt, by younger workers, to follow on with more modern revisions of a few of the many groups dealt with by Malloch.

There is no doubt that revisions are needed, but the basic framework of classification and species has been provided for us, under the difficult conditions imposed by small collections being sent abroad for study. Our task is now to convert this structural framework into a fuller knowledge.

Had Malloch not co-operated so fully in studying our local Diptera we would probably still be facing the construction of this framework, and we are greatly indebted to him for the task he has performed on our behalf.

3. Key to Abbrevations and Notes on Interpretation.

(*a*) *Abbreviations.*

Type material of Diptera from the Australasian Region has been located in seventeen collections. These are referred to in the list of species under the following abbreviations:

SPHTM.—School of Public Health and Tropical Medicine, University of Sydney, Sydney, New South Wales, Australia.

Aust. M.—The Australian Museum, College Street, Sydney, New South Wales, Australia.

NSW Dept. Agr.—The New South Wales Department of Agriculture, Farrer Place, Sydney, New South Wales, Australia.

CSIRO.—Division of Entomology, Commonwealth Scientific and Industrial Research Organization, Australian Capital Territory, Australia.

S.A. Mus.—The South Australian Museum, Adelaide, South Australia, Australia.

Cawthron.—The Cawthron Institute, Nelson, New Zealand.

C'bury M.—The Canterbury Museum, Christchurch, New Zealand.

Bishop M.—The Bernice P. Bishop Museum, Honolulu, Hawaii.

USNM.—The United States National Museum, Washington, D.C., United States of America.

BM(NH).—The British Museum (Natural History), Cromwell Road, London, England.

Bruxelles.—Musée Royale d'Histoire Naturelle de Belgique, Rue Vautier 31, Bruxelles, Belgium.

Leiden.—Rijksmuseum van Natuurlijke Historie, Leiden, Holland.

Amsterdam.—Zoologisch Museum, Zeeburgerdijk 21, Amsterdam, Holland.

Budapest.—Orszagos Termeszettudomanyi Muzeum, Baross Utca 13, Budapest VIII, Hungaria.

DEI.—Deutsches Entomologisches Institut, Berlin—Friedrichshagen, Waldostrasse I, Germany.

Hamburg.—Zoologisches Staatinstitut und Zoologisches Museum, Hamburg 13, Bornplatz 5, Germany.

Vienna.—Naturhistoriches Museum in Wien, Wien, 1, Burgring 7, Austria.

Throughout the various lists literature references have been cited with a key number (M1–M135) followed by page references in brackets. The key numbers refer to the individual papers, serially listed, in the bibliography. In a few cases a serial number, e.g. M110 (*a*), covers more than one individual paper which appeared consecutively in the one publication. An attempt has been made to keep the papers in strict chronological order, but this has occasionally broken down within a particular year when publication in more than one journal has been involved. This means that in a few cases the reference with the lowest key number may not be the first reference to the species in question.

(*b*) *Notes on Interpretation.*

(i) *Scope of the Species List.*

We have endeavoured to list every species dealt with by Malloch from the Australasian Region which, for the convenience of this publication we interpret as Australia, Timor, islands northward to the Moluccas, and all islands of the Pacific eastward and southward from New Guinea to Hawaii. An occasional species from just outside this area has been included, but all strictly Oriental species have been excluded.

This species list is built up from the papers listed in the bibliography and from the material handled by Malloch. Occasionally no reference is given for a species although material identified by Malloch is listed. This simply means that the species in question has been identified by Malloch but not dealt with in the literature. All references by Malloch to Australasian species that we have discovered have been entered with the one important exception of his Catalogue of Australian Tachinidae (M47). This being in itself a full catalogue, we considered it would be redundant to republish the information which is already in its most useful form. The occasional references to this Catalogue have occurred because Malloch has identified certain of the species listed without discussing them in any subsequent paper.

(ii) *Holotypes.*

Malloch infrequently used the term "holotype", the majority of his citations and labels being simply "type". As his intentions are clear we have consistently used "holotype" in the lists for the more ready differentiation of other kinds of types.

Although the majority of relevant types have been located there does remain a residue for which information is lacking. It is difficult to be positive that a missing

type is no longer in existence. For instance, types supposed to be in Hamburg and destroyed by bombing during World War II were eventually found in Malloch's collection. However, evidence of insect damage in Malloch's collection was obvious when handed over to the United States National Museum, and some types may have been destroyed. Also one of us (D.J.L.) did see Malloch type labels on empty pins in the School of Public Health and Tropical Medicine Collection in 1946, but these labels can no longer be located. Hence some types are known to have been lost in this way, but which ones remains in doubt. Further, there are records of certain types being received in this school in 1934 and the records include annotations that they were to go, or did go, to the Macleay Museum, University of Sydney, but no trace of these can now be found. Finally, there are a number of types of Calliphoridae, approximately ten, for which there is presumptive evidence that they were returned to Australia but which cannot be traced, nor is there any known record concerning them.

Whenever no holotype has been located, if there is any evidence as to what may have happened to it this is indicated in a footnote.

(iii) *Allotypes.*

Although cited in his descriptions allotypes have not been regarded as of great importance by Malloch, and he has frequently labelled them "paratypes", although it is clear from his descriptions that a particular "paratype" specimen is the one referred to as allotype. Some such cases have been noted in the species list but there are undoubtedly others which have not been detected.

(iv) *Paratypes.*

In so far as possible specimens listed as paratypes have been checked with the original descriptions to make sure they were available to the author at the time the species in question was described. This procedure has been followed in the main by the authors but not by our other collaborators. Since Malloch has attached paratype labels to specimens seen after publication of a species, a reviewer should take precautions to assess the authenticity of paratype material before using it as a basis of redescription. For example, *Pseudoleucopis flavitarsis* was published in 1925, only the type being listed. In his collection was found a specimen labelled "paratype" but only collected in 1926, and referred to in the literature in 1930. Many other such cases of liberality with "paratypes" have been detected, hence our note of caution regarding the interpretation of the status of specimens labelled "paratype", since those designated subsequent to time of publication, and not examined during the description of the species cannot be valid paratypes.

(v) *Details of Labels.*

There are many cases of discrepancy between the collection data as published and that appearing on the actual label. Wherever such instances have been detected they have been noted, but there will be more and reviewers should keep this in mind in case the relevant data are of significance. At times, too, there is a discrepancy between the name of the species as published and that appearing on the type label. The published name must stand, of course, but where such discrepancies have been detected they have been noted.

(vi) *Unpublished Names.*

Quite a number of types have been found, both in Australia and in the United States National Museum, the names of which do not appear to have been published. In the main we have been convinced that most of these are unpublished, although it is still possible that our search of the literature has been incomplete despite our endeavours to the contrary.

In those cases where the unpublished name is confused with a description under some other name we have included the *nomen nudum* in our list. Otherwise unpublished names have been suppressed, in order to avoid adding such *nomina nuda* to the literature.

(vii) *Location of Type Material.*

Malloch did not consistently indicate the sources of his material and where the types were to be lodged. This has led, in the past, to a great deal of confusion as to the whereabouts of his types. Furthermore, even when the types are stated to be in a certain institution it has not always meant that they did in fact reach the institution named. Added to this, Malloch's own collection has been inaccessible for a number of years, and even the collection housed in this School was not organized in such a way that a student could be certain of finding the material he wished to examine. All this meant that only limited reference could be made to the material on which Malloch based his extensive literature.

Most of the material examined by Malloch has now been located and its location is revealed in the present lists.

Since Malloch's correspondents were often individuals rather than institutions it was inevitable that some types did not end up in the collections in which they are stated to be lodged. Indeed this is a common occurrence. Further, some of the institutions no longer maintain collections and have transferred them elsewhere. In particular the important collection of the late Dr. Eustace Ferguson, once held by the New South Wales Department of Health, is now housed in the School of Public Health and Tropical Medicine, University of Sydney. Certain private collections have also been dissipated in various ways, but the major changes in type locations have been due to the changes in employment of some of Malloch's correspondents.

It would be more than a major task at this stage to try to reestablish types in conformity with the statements in the literature. Since the present dispersion of the collections in question no longer conforms with the literature, such a procedure would never be completely successful. This is the basis of the significance of publication of the lists of present type locations, since there is every reason to believe that stability has now been realized.

It is also obvious that the second World War did impede the return distribution of type material by Malloch. Many types were discovered in Malloch's private collection which became the property of the United States National Museum in 1949. Among this material it was obvious that quite a considerable number of the types should have been returned to a variety of museums and through the generosity of the U.S. National Museum these are being returned to the country of origin whenever this intention has been expressed in the literature.

(viii) *Synonymy.*

Since we have listed all specific names used by Malloch any synonymy for which he is responsible will be revealed when the species references are consulted. Other later synonymy for which authors other than Malloch are responsible has been ignored because we were only concerned with Malloch's literature as such and because it would be impossible for us to cover completely the subsequent literature, for all the groups dealt with by Malloch, in order to include all recent changes in specific status.

(ix) *Genera.*

Species are listed in the genera in which Malloch included them. Changes in generic interpretation have taken place and where Malloch has been responsible for such changes, or where he has accepted changes proposed by other authors, these are revealed by the species being listed under each generic name. The occurrence of brackets around Malloch's name as author will provide a ready indication that such changes have occurred.

(x) *Family Names.*

The family names used are those employed by Malloch. Changes in family concepts have also occurred and the entry of two or more family names after a generic name is an indication of varying family concepts. Certain family names, e.g. Ortalidae, were used by Malloch over a long period but his later papers reveal the adoption of an alternative name, as in the case cited, of Otitidae. In such cases we have tried to be consistent in using the earlier name as well as the later one in references subsequent to the change.

(xi) *Spelling.*

Although we are aware that the spelling of some specific names used by Malloch is not correct, and in some cases has been corrected in recent literature, we have tried to be consistent in quoting Malloch accurately. Any variations from the spelling used by Malloch which may be detected are not corrections on our part but will be simply typographical errors.

4. List of Families with Cross References to the Bibliography.

AGROMYZIDAE: M12 (622); M18 (335-338); M24 (88-93); M25 (335-339); M31 (546-547); M35 (7-8); M38 (421-428); M86 (213-216); M104 (1-2); M110 (340-342); M111 (18-19); M130 (266).

ANTHOMYZIDAE: M102 (113-114); M115 (260-261).

ASILIDAE: M43 (296-300); M46 (607-611); M56 (408-410).

ASTEIIDAE: M18 (338); M38 (445-446); M40 (23-26); M71 (231-233); M80 (321-322); M93 (115-116); M112 (190-192); M115 (259-260).

BIBIONIDAE: M46 (602-606).

BOMBYLIIDAE: M16 (205); M46 (606-607); M51 (138-140).

BORBORIDAE (SPHAEROCERIDAE): M1 (236-237); M24 (85-86); M44 (325-326); M102 (260-262); M111 (23-24); M116 (323-325).

CALLIPHORIDAE: M20 (638-640); M32 (498); M33 (205); M36 (299-335); M44 (328-329); M45 (360); M46 (612-613); M55 (283); M62 (269-272); M64 (256-257); M69 (436-447); M72 (313-324); M73 (233-237); M75 (481-483); M84 (64-68); M92 (13-16); M107 (12-22); M110 (365); M114 (21-23); M119 (186 and 190).

CHLOROPIDAE: M12 (619-621); M18 (329-333); M19 (354-359); M24 (94-97); M25 (335-339); M31 (546); M38 (428-445); M43 (300-303); M74 (243-250); M78 (60-76); M83 (404-421); M96 (216-217); M111 (27-30); M114 (23-26); M116 (334-356); M128 (261-288); M134 (41-64).

CLUSIOIDIDAE (CLUSIIDAE): M30 (47-48); M63 (99); M66 (199-201); M69 (434-435); M96 (215); M135 (209).

COELOPIDAE: M101 (345-350).

DIOPSIDAE: M117 (437-438).

DROSOPHILIDAE: M12 (611-619); M19 (348-354); M24 (87-88); M25 (334-335); M35 (1-7); M40 (23-26); M45 (354-358); M76 (331-332); M96 (217-223); M109 (90); M106 (267-311); M111 (19-23); M112 (192-196).

EMPIDIDAE: M69 (449-450); M83 (424-428); M97 (458).

EPHYDRIDAE: M18 (333-335); M24 (86-87); M25 (324-332); M31 (545-546); M34 (5-17); M45 (353-354); M71 (245); M105 (1); M106 (312-323); M111 (3-16); M112 (196-200).

GEOMYZIDAE: M24 (93-94).

HELCOMYZIDAE: M103 (325-327).

HELOMYZIDAE: M7 (227); M31 (551-552); M39 (83-100); M72 (333-344); M80 (294-295); M103 (183-184 and 200-202).

LONCHAEIDAE: M43 (304-307); M74 (239-243).

MICROPEZIDAE: M110 (342-348).

MILICHIIDAE: M78 (76-78); M106 (325-329); M111 (3).

MUSCIDAE: M4 (428-430); M5 (237-239); M6 (414-420); M8 (272-280); M9 (135-143); M10 (351-359); M11 (574); M12 (601-611); M13 (666-674); M14 (184-193); M15 (513-514); M17 (138-146); M21 (415); M22 (322-338); M23 (35-46); M25 (339-340); M26 (139-142); M27 (329-330); M28 (115); M29 (508); M30 (48-49); M31 (553-554); M44 (326-328); M49 (297 and 333-334); M50 (468); M52 (80-81); M55 (283); M58 (151-175); M60 (390-408); M62 (262-264); M65 (326-333); M72 (289-306); M83 (379-383); M89 (402 and 506); M95 (193-203); M107 (7-9); M108 (77-78); M119 (254-256).

MYCETOPHILIDAE: M46 (599-602); M54 (107).

NEOTTIOPHILIDAE: M31 (552-553); M35 (16); M69 (435-436); M86 (217); M109 (94-95).

NERIIDAE: M110 (343).

OCHTHIPHILIDAE: M70 (488-491); M86 (216-217); M130 (266).

OPOMYZIDAE: M71 (235-242).

ORTALIDAE (OTITIDAE): M24 (85); M31 (547-548); M45 (343-353); M46 (611-612); M57 (505-516); M63 (99-100); M69 (429-434); M70 (491-492); M71 (243-244); M73 (215-231); M82 (1-28); M96 (205-215); M98 (36); M103 (262); M121 (97-154); M129 (66-88); M131 (19-20); M135 (205-208).

PHORIDAE: M2 (433, 501, 514); M25 (332-334); M109 (95); M110 (329-340); M111 (30-31).

PHYTALMIIDAE: M122 (169-180); M129 (88-98).

PIOPHILIDAE: M25 (315-316); M35 (8); M43 (309); M74 (251); M80 (292-293); M96 (215); M103 (246).

PSYCHODIDAE: M3 (265).

PYRGOTIDAE: M53 (1-31); M120 (51-53).

RHAGIONIDAE: M79 (273-276); M88 (112 and 116).

SAPROMYZIDAE: M24 (81-85); M25 (316-324); M30 (31-47); M31 (548-551); M34 (20-26); M35 (8-15); M38 (399-421); M41 (102); M42 (162-163); M44 (319-322); M45 (355-360); M59 (37, 58, 65, 68, 80); M61 (409-414); M63 (97-98); M65 (322); M66 (201-213); M69 (434); M71 (244); M91 (3-12); M98 (34-36); M109 (87-90); M111 (24-27); M112 (180-189); M125 (447-449); M132 (20-22); M133 (132-145).

SCIOMYZIDAE: M7 (228); M24 (80-81); M44 (322-325); M48 (151-178); M72 (343-344); M113 (95-96); M130 (266).

SEPSIDAE: M25 (311-315); M43 (307-309); M46 (611-612).

STRATIOMYIIDAE: M45 (360-366).

SYRPHIDAE: M1 (233-236); M7 (227); M109 (87).

TACHINIDAE: M37 (336-353); M44 (329-335); M46 (614-617); M47 (651-662); M54 (107-117); M55 (283-343); M67 (92-135); M68 (303-353); M72 (307-311 and 325-331); M77 (130); M78 (78); M80 (295-298); M83 (385-388); M85 (127-132); M87 (273-274); M97 (431-454); M99 (74-79); M100 (135-139); M104 (2-8); M107 (24); M108 (74-76); M110 (348-365); M114 (10-20); M119 (162-252); M124 (64).

TETHINIDAE: M109 (91-94); M111 (16-18).

THEREVIDAE: M90 (241-242).

TRYPETIDAE: M81 (253-266); M83 (391-404); M94 (145-147); M103 (274); M112 (200); M118 (111-116); M123 (331-334); M124 (409-465); M126 (228-278); M127 (239-242); M135 (202).

5. List of Subfamilies, Tribes and Groups, with Cross References to the Bibliography.

(*N.B.*—This list includes only references to the above groupings when the individual groups are discussed as such. References in which the subfamily, tribe or group is not disclosed are not included.)

Actiini (Tachinidae): M54 (114-117); M68 (303-310); M110 (364); M114 (20).

Adramini (Trypetidae): M123 (331-334); M124 (413-415); M126 (246-250).

Agromyzinae (Agromyzidae): M18 (337-338); M24 (89-92).

Armeniini (Tachinidae): M37 (342-345); M44 (329-330); M46 (614); M55 (285-286); M67 (101-104); M99 (74-77).

Angitulinae (Phytalmiidae): M122 (170).

Anthomyiinae (Muscidae): M4 (428-429); M17 (138-139); M25 (339-340); M30 (48); M60 (390-391); M72 (290-291).

Asilinae (Asilidae): M46 (609-611).

Beridinae (Stratiomyiidae): M45 (361-365).

Botanobiinae (Chloropidae): M24 (95-97); M25 (335-339); M31 (546); M38 (434-445); M43 (300-303).

Calliphorinae (Calliphoridae): M36 (301-324); M46 (613); M72 (315-324); M73 (234-237); M92 (15-16); M107 (11-20).

Calliphorini (Calliphoridae): M72 (315-318).

Canaceinae (Ephydridae): M18 (333-334); M24 (86-87); M34 (5-6); M111 (4-6).

Ceratitinae (Trypetidae): M81 (265).

Ceratomerinae (Empididae): M83 (428-429).

Ceroplatinae (Mycetophilidae): M46 (599-602).

Chamaemyiinae (Sciomyzidae): M130 (266).

Chloropinae (Chloropidae): M24 (94-95); M38 (428-434); M74 (248-250); M78 (67-73); M83 (414-421); M116 (334-356).

Chlorotachina (Tachinidae): M55 (323-327).

Chrysomyiinae (Calliphoridae): M36 (324-328); M72 (314-315); M73 (233-234); M107 (21).

Clinocerinae (Empididae): M83 (428).

Coenosiinae (Muscidae): M5 (239); M10 (380-383); M22 (331-333); M58 (157-159).

Cylindromyiini (Tachinidae): M55 (289-291); M68 (312-316); M83 (385-388).

Dacinae (Trypetidae): M81 (254-265); M124 (410-415); M126 (228-250).

Dacinii (Trypetidae): M124 (410-413); M126 (228-246).

Dasypogoninae (Asilidae): M43 (299-300); M46 (607-608).

Dexiini (Tachinidae): M55 (315-316); M67 (109-128); M85 (127-132); M110 (364-365).

Drosophilinae (Drosophilidae): M76 (331-332).

Empidinae (Empididae): M69 (448-450); M83 (424-427).

Ephydrinae (Ephydridae): M18 (334-335); M24 (86); M25 (327-332); M32 (10-12); M106 (322-323); M111 (6-16).

Euthera (Tachinidae): M55 (332-333).

Exorista (Tachinidae): M55 (330-332).

Fanniinae (Muscidae): M12 (605-606); M17 (146); M58 (156-157); M72 (305).

Gonia (Tachinidae): M55 (320-323).

Group I (Trypetidae): M124 (415-439).

Group II (Trypetidae): M124 (439-440).

Group III (Trypetidae): M124 (440-454).

Haematobiini (Muscidae): M89 (506).

Hemerodromiinae (Empididae): M69 (450); M83 (428).

Homalocneminae (Empididae): M83 (428); M97 (458).

Hydrellinae (Ephydridae): M34 (14-17).

Laphriinae (Asilidae): M43 (297-299); M46 (609).

Leskiini (Tachinidae): M67 (128-133).

Linnaemyiini (Tachinidae): M55 (316-320); M68 (310-311).

Lispinae (Muscidae): M8 (280); M10 (384-389); M12 (606-611); M22 (333-338); M25 (340); M58 (153-156); M60 (391-392); M95 (193-195).

Metopiinae (Calliphoridae): M36 (334-335); M69 (436-447).

Microtropezini (Tachinidae): M46 (614-615); M55 (286-288); M67 (99-101).

Milichiinae (Agromyzidae): M18 (335-336); M24 (88-89); M31 (546-547); M35 (7-8).

Muscinae (Muscidae): M31 (553-554); M49 (328-335); M58 (173-174); M60 (407-408); M62 (264); M72 (305-306); M95 (203).

Notiphilinae (Ephydridae): M25 (324-327); M34 (12-13); M106 (313-321).

Ochthiphilinae (Agromyzidae, Ochthiphilidae or Sciomyzidae): M24 (92-93); M25 (335).

Oscinosominae (Chloropidae): M74 (244-248); M78 (60-67); M83 (404-414); M128 (261-288); M134 (41-64).

Pachygastrinae (Stratiomyiidae): M45 (365-366).

Palpostomini (Tachinidae): M37 (337-342); M55 (334); M67 (133-135).

Phaoniinae (Muscidae): M4 (429-430); M5 (237-239); M6 (414-420); M8 (272-275); M9 (135-143); M11 (574); M12 (601-605); M13 (666-674); M17 (139-146); M21 (415); M22 (322-331); M23 (39-45); M25 (340); M30 (48-49); M31 (554); M49 (290-328); M50 (463-469); M55 (283); M58 (160-173); M60 (392-407); M62 (262-264); M65 (326-333); M72 (292-305); M83 (379-383); M95 (196-202); M119 (254-256).

Phasiini (Tachinidae): M54 (108-113); M55 (284-285); M67 (92-99); M72 (307-311).

Phorocera (Tachinidae): M55 (327-330).

Platystominae (Ortalidae): M121 (98-154); M129 (67-88); M45 (343-351); M69 (429-434); M73 (219-231).

Polleniini (Calliphoridae): M72 (318-324).

Rhiniinae (Calliphoridae): M32 (498); M36 (328-334); M46 (612-613); M55 (283).

Rivelliinae (Ortalidae): M45 (351-353).

Rutiliini (Tachinidae): M37 (345-353); M44 (330-335); M46 (615-617); M55 (291-315); M67 (104-109); M78 (78); M110 (348-351); M114 (10-20).

Sarcophaginae (Calliphoridae): M36 (334); M62 (269-272); M75 (481-483); M92 (13-15); M107 (21-23).

Schistopterinae (Trypetidae): M124 (463).

Sciomyzinae (Sciomyzidae): M44 (324-325).

Sepedonini (Sciomyzidae): M44 (322-324).

Stomoxydinae (Muscidae): M89 (402-403); M89 (506).

Sturmiini (Tachinidae): M110 (351-364).

Tachinini (Tachinidae): M54 (113-114); M55 (320-334); M68 (316-353).

Tephritinae (Trypetidae): M124 (454-463).

Tethinae (Agromyzidae): M18 (336-337).

Toxurinii (Pyrgotidae or Ortalidae): M53 (23-30).

Trypetinae (Trypetidae): M81 (266); M124 (415-454); M126 (250-278).

Ulidiinae (Ortalidae): M73 (215-219); M121 (97-98); M129 (66-67).

Voria (Tachinidae): M55 (333-334).

6. List of Genera with Cross References to the Bibliography.

Acanthoneura Macq. (Trypetidae): M124 (432-435) and (464).
Achias Fabr. (Ortalidae): M45 (351); M121 (134-138).
Achiosoma Hendel (Ortalidae): M121 (130-131).
Acinia R.-D. (Trypetidae): M124 (460).
Acropyrgota Hendel (Pyrgotidae): M53 (15-16).
Acrostichalia Tonn. & Mall. (Helomyzidae): M39 (87); M103 (200-202).
Acrosticta Loew (Ortalidae): M73 (217); M96 (206-207); M103 (262).
Actia R.-D. (Tachinidae): M54 (116); M55 (334); M68 (304-310); M77 (130); M110 (364); M114 (20).
Actina Latr. (Stratiomyiidae): M45 (364).
Acucera Mall. (Tachinidae): M68 (328).
Adapsilia Waga (Pyrgotidae): M53 (16-17 and 31); M120 (51-52).
Adrama Walk. (Trypetidae): M123 (332-334); M126 (247-250).
Aenigmetopia Mall. (Calliphoridae): M69 (447).
**Aequia* Mall. (Tachinidae): M68 (325).
Agromyza Fall. (Agromyzidae): M12 (622); M24 (90); M38 (424-428); M110 (340).
Allophylina Tonn. & Mall. (Helomyzidae): M39 (88).
Allophylopsis Lamb (Helomyzidae): M39 (91-99).
Altaia Mall. (Tachinidae): M119 (209-210).
Amedoria B. & B. (Tachinidae): M110 (364).
Amenia R.-D. (Tachinidae): M37 (343-344); M46 (614); M55 (286); M67 (101-102); M99 (74-77).
Amiota Loew (Drosophilidae): M12 (612).
Amphibolia Macq. (Tachinidae): M37 (349); M55 (312).
Amphibolosia Surcouf (Tachinidae): M68 (310).
Amphicyphus Meig. (Sapromyzidae): M31 (550).
Amplipila Curran (Tachinidae): M55 (336); M68 (347).
Amplipilis = *Amplipila* Curran (Tachinidae): M68 (347).
Anabarrhynchus Macq. (Therevidae): M90 (241).
Anaclysta Stein (Muscidae): M12 (602-603).
Anamastax B. & B. (Tachinidae): M54 (114).
Anaperistommyia Town. (Tachinidae): M80 (296).
Anatropomyia Mall. (Tachinidae): M67 (127).
Andrenosoma Rond. (Asilidae): M43 (299).
Aneuria Mall. (Helomyzidae): M72 (340-343).
Angitula Walk. (Phytalmiidae): M122 (170); M129 (90).
Angitulina Ender. (Phytalmiidae): M122 (179).
Angituloides Hendel (Phytalmiidae): M122 (169); M129 (90-91).
Anomoia Walk. (Trypetidae): M124 (449); M126 (275).
Anthomyia Meig. (Muscidae): M23 (37); M60 (390).
Anthracomyia Mall. (Calliphoridae): M36 (319); M45 (360).
Anthracomyza Mall. (Calliphoridae): M36 (319); M45 (360).
Antineura O.S. (Ortalidae): M121 (104).
Antipodomyia Mall. (Muscidae): M4 (429-430); M23 (44); M49 (297).
Antriadophila Skuse (Mycetophilidae): M46 (599-600).
Apactoneura Mall. (Ortalidae): M73 (223-224).
Apalpostoma Mall. (Tachinidae): M67 (134-135).
Apalpus Mall. (Tachinidae): M55 (318).
Apemon Johannsen (Mycetophilidae): M46 (600).
Aphaniosoma Beck. (Geomyzidae): M24 (94).
Aphiochaeta Brues (Phoridae): M2 (514); M110 (334).
Aphritis Latr. (Syrphidae): M1 (236).
Apilia Mall. (Tachinidae): M68 (345-346); M80 (298).
Apocephalus Coq. (Phoridae): M109 (95).
Aprometopis Beck. (Chloropidae): M114 (23).
Apterina Macq. (Borboridae): M102 (261).
Apteroscinis Mall. (Chloropidae): M83 (407-408).
Apulvillus Mall. (Ephydridae): M112 (198-199).
Apyrgota Hendel (Pyrgotidae): M53 (3).
Archiphytalmia Ender. (Phytalmiidae): M122 (172 and 180).
Arctoneura Hutt. (Mycetophilidae): M46 (599-600).
Arnomyia Mall. (Sapromyzidae): M63 (97-98).
Arrhenomyza Mall. (Tachinidae): M55 (322).
Arthuria Mall. (Tachinidae): M119 (166-167).
Asetulia Mall. (Tachinidae): M119 (188-189).
Asilus Linné (Asilidae): M46 (610-611).
Asindulum Latr. (Mycetophilidae): M46 (599-600).
Assuania Beck. (Chloropidae): M78 (69-70).
Asteia Meig. (Asteiidae): M71 (231-233).
Astiosoma Duda (Asteiidae): M76 (322); M93 (115-116); M112 (190-192).
Asyntona O.S. (Ortalidae): M121 (122); M129 (76).
Atherigona Rond. (Muscidae): M14 (184-192); M17 (145); M28 (115); M44 (326-327); M58 (158-159); M60 (396-397); M95 (201-202).
Atherimorpha White (Rhagionidae): M79 (275).
Atherix Meig. (Rhagionidae): M79 (274); M88 (112).
Atomosia Macq. (Asilidae): M43 (297).
Atopognathus Big. (Phytalmiidae): M122 (180).
Atrichopleura Bez. (Empididae): M83 (424-425).
Australina Mall. (Sapromyzidae): M25 (323).
Australophyra Mall. (Muscidae): M13 (667); M31 (554).
Australosepsis Mall. (Sepsidae): M25 (314-315); M43 (307).
Austrodexia Mall. (Tachinidae): M67 (123-126).
Austroleptis Hardy (Rhagionidae): M79 (274).
Austrometopia Mall. (Calliphoridae): M69 (438).
Austrophorocera Town. (Tachinidae): M68 (344).
Avibrissia Mall. (Tachinidae): M97 (437).
Avibrissina Mall. (Tachinidae): M97 (438-439); M119 (179).
Balioglutum Aldr. (Muscidae): M23 (45-46).
Batrachomyia Skuse (Chloropidae): M25 (336); M38 (440-441); M128 (264-265).
Benjaminella Mall. (Chloropidae): M25 (337); M128 (267).
Beris Latr. (Stratiomyiidae): M45 (363).
Berisina Mall. (Stratiomyiidae): M45 (365).
Bibio Geoff. (Bibionidae): M46 (602).
Borboroides Mall. (Borboridae): M24 (85-86).
Botanobia Lioy (Chloropidae): M25 (338-339); M38 (445); M134 (57-64).
Brachydeutera Loew (Ephydridae): M18 (335); M45 (353-354).
Brea Walk. (Ortalidae): M121 (124-125).
Bunostoma Mall. (Drosophilidae): M96 (219-220); M112 (193).
Byomya R.-D. (Muscidae): M49 (333-335); M58 (174); M95 (203).

* The generic name *Aequia* is mentioned in the discussion on *Hyalomyodes*, M68 (325). It is evident that Malloch first intended to describe the species preceding this discussion in a new genus *Aequia* but later identified it as *Leucostoma simplex* (Fallen), and failed to make the appropriate alteration in the following text. *Aequia* is thus a generic *nomen nudum*.

Cadrema Walk. (Chloropidae): M74 (246); M83 (404-407); M96 (216); M111 (28-29); M128 (277-279).
Cairusimyia Mall. (Helomyzidae): M80 (294-295).
Calcager Hutt. (Tachinidae): M55 (342); M119 (174-175); M119 (239-240).
Calcageria Curran (Tachinidae): M55 (342); M119 (172-175).
Calliphora R.-D. (Calliphoridae): M20 (640); M36 (303-318); M46 (613); M72 (316); M73 (234); M84 (64-67); M92 (15-16); M107 (19-20); M119 (186).
Calliphoroides Mall. (Muscidae): M72 (306).
Callistomyia Bez. (Trypetidae): M124 (447-448).
Callopistromyia Hendel (Ortalidae) (Otitidae): M96 (211).
Calloplatyura Mall. (Mycetophilidae): M46 (601).
Calobata Meig. (Micropezidae): M110 (343-348).
Calopygidia Mall. (Tachinidae): M68 (350-351).
Calotachina Mall. (Tachinidae): M119 (176-177).
Camaromyia Hendel (Trypetidae): M103 (274); M124 (460-461).
Campylia Mall. (Tachinidae): M119 (239-240).
Campylocera Macq. (Pyrgotidae): M53 (17-18) and (30-31).
Canace Haliday (Ephydridae): M24 (87); M111 (4).
Caricea R.-D. (Muscidae): M22 (332-333).
Carpophthorella Hendel (Trypetidae): M124 (448); M126 (263-264).
Casa Hutt. (Mycetophilidae): M46 (600).
Catharosia Rond. (Tachinidae): M80 (295).
Caviceps Mall. (Chloropidae): M19 (356); M128 (275).
Celetor Loew (Ortalidae): M57 (506).
Cephaloconus Walk. (Sapromyzidae): M109 (89-90); M125 (448-449); M133 (145).
Cerataulina Hendel (Sapromyzidae): M41 (102).
Ceratitella Mall. (Trypetidae): M124 (452-453).
Ceratitis McLeay (Trypetidae): M124 (451).
Ceratolauxania Hendel (Sapromyzidae): M38 (408-409).
Ceratomerus Philippi (Empididae): M83 (428-429).
Cerodonta Rond. (Agromyzidae): M24 (89-90); M38 (423-424).
Ceroplatus Bosc. (Mycetophilidae): M46 (600).
Cerosomyia Hutt. (Tachinidae): M119 (196-199).
Cerotelion Rond. (Mycetophilidae): M46 (600).
Cestrotus Loew (Sapromyzidae): M133 (134).
Chaetocoelopa Mall. (Coelopidae): M101 (350).
Chaetodacus Bez. (Trypetidae): M94 (145-146).
Chaetogaster Macq. (Tachinidae): M37 (353); M55 (315); M114 (19-20).
Chaetogastrina Mall. (Tachinidae): M55 (313-314).
Chaetolauxania Kert. (Sapromyzidae): M61 (410).
Chaetoleucopis Mall. (Agromyzidae) (Ochthiphilidae) (Sciomyzidae): M86 (216-217).
Chaetilispa Mall. (Muscidae): M12 (606).
Chaetometopia Mall. (Calliphoridae): M69 (443-444).
Chaetomosillus Hendel (Ephydridae): M105 (1).
Chaetophthalmus B. & B. (Tachinidae): M55 (319); M68 (311).
Chaetopsiophila Mall. (Piophilidae): M43 (309); M80 (293).
Chaetopsis Loew (Ortalidae) (Otitidae): M96 (207).
Chaetorivellia de Meij. (Ortalidae) (Otitidae): M121 (127).
Chaetoscatella Mall. (Ephydridae): M106 (322-323); M112 (199-200).
Chamaemyia Panzer (Ochthiphilidae): M70 (491).
Cheesmanomyia Mall. (Trypetidae): M124 (120).
Chelipoda Macq. (Empididae): M83 (428).
Chilocrypius Mall. (Sapromyzidae): M111 (26-27); M112 (188-189).
Chloromerus Beck. (Chloropidae): M18 (332); M38 (431-434); M78 (68); M116 (336-337).
Chloropella Mall. (Chloropidae): M24 (94-95).
Chloropisca Loew (Chloropidae): M38 (429-430); M83 (414); M116 (353-354).
Chlorops Meig. (Chloropidae): M74 (250); M78 (70-73); M83 (420-421); M116 (337).
Chloropsina Mall. (Chloropidae): M18 (333).
Chlororhinia Town. (Calliphoridae): M32 (498); M36 (332); M55 (283).
Chlorotachina Town. (Tachinidae): M37 (353); M55 (324-326).
Chonocephalus Wand. (Phoridae): M110 (339-340).
Chorisops Rond. (Stratiomyiidae): M45 (364).
Chrysomyia R.-D. (Calliphoridae): M20 (639); M33 (205); M36 (327-328); M72 (315); M73 (233-234); M107 (21).
Chrysomyza Fall. (Ortalidae): M24 (85); M73 (215); M129 (67); M135 (205).
Chrysopasta B. & B. (Tachinidae): M46 (616); M55 (307); M67 (105-106).
Chrysopilus Macq. (Rhagionidae): M79 (276); M88 (116).
Chrysopogon Roed. (Asilidae): M43 (300).
Chrysotrypanea Mall. (Trypetidae): M124 (457-458).
Cladodromia Bez. (Empididae): M83 (428).
Clasiopa Stenhammar (Ephydridae): M34 (13).
Cleitamia Macq. (Ortalidae) (Otitidae): M121 (107-112).
Cleitamoides Mall. (Ortalidae) (Otitidae): M121 (107).
Clusiosoma Mall. (Ortalidae) (Trypetidae): M31 (548); M124 (425-427); M126 (259).
Coelopa Meig. (Coelopidae): M101 (345).
Coelopella Mall. (Coelopidae): M101 (348).
Coenolispa Mall. (Muscidae): M95 (194-195).
Coenosia Meig. (Muscidae): M22 (332).
Colobostrella Hendel (Trypetidae): M124 (446).
Colobostroter Ender. (Trypetidae): M124 (418-419); M124 (441).
Compsilura Bouche (Tachinidae): M110 (360).
Conicipithea Hendel (Ortalidae) (Otitidae): M121 (103).
Conioscinella Duda (Chloropidae): M128 (280-287).
Copromyza Fall. (Borboridae) (Sphaeroceridae): M106 (323).
Cristobalia Mall. (Trypetidae): M124 (448); M126 (265).
Cryptochaetum Rond. (Agromyzidae) (Ochthiphilidae) (Sciomyzidae): M38 (421-423); M70 (490).
Cuphocera Macq. (Tachinidae): M68 (316-318).
Cycasia Mall. (Trypetidae): M135 (203).
Cyclopsia Mall. (Trypetidae): M124 (445).
Cylindromyia Meig. (Tachinidae): M55 (291); M68 (312-316).
Czernyola Bez. (Clusioïdidae) (Clusiidae): M135 (209).
Dacus Fabr. (Trypetidae): M81 (254-265); M94 (145-146); M118 (112-115); M124 (411-413); M124 (464); M126 (228-246).
Dasycoelopa Mall. (Coelopidae): M101 (349-350).
Dasydrosophila Duda (Drosophilidae): M106 (291).
Dasyomma Macq. (Rhagionidae): M79 (275).
Dasyortalis Hendel (Ortalidae) (Otitidae): M57 (506); M121 (102-103); M129 (68).

Dasyrhicnoessa Hendel (Agromyzidae) (Tethinidae): M109 (93-94).
Delta Mall. (Tachinidae): M68 (332-335); M80 (298).
Deltastoma Mall. (Chloropidae): M19 (359); M38 (442); M78 (66-67); M128 (275).
Deltomyza Mall. (Tachinidae): M68 (332-335); M80 (298).
Degeeria Meig. (Tachinidae): M110 (362-363).
Demoticus Macq. (Tachinidae): M55 (332); M67 (129).
Depressa Mall. (Sapromyzidae): M30 (31-32); M38 (400-402).
Deromyia Philippi (Asilidae): M43 (299).
Desmometopa Loew (Agromyzidae) (Milichiidae): M18 (336); M35 (7-8); M106 (327-328).
Dexia Meig. (Tachinidae): M55 (316).
Dexopollenia Town. (Calliphoridae): M36 (324).
Diarrhegmoides Mall. (Trypetidae): M124 (437-438).
Dichaetomyia Mall. (Muscidae): M6 (420); M17 (140); M22 (322-327); M27 (329-330); M50 (468-469); M58 (170-173); M60 (400-407); M107 (7).
Dichaetophora Rond. (Sciomyzidae): M44 (323-324).
Dicladochaeta Mall. (Drosophilidae): M96 (218); M112 (195).
Dilophus Meig. (Bibionidae): M46 (602).
Dimeringophrys Ender. (Trypetidae): M124 (441).
Dioides Kert. (Sapromyzidae): M133 (134).
Diplochorda O.S. (Phytalmiidae): M122 (175-179); M129 (90).
Diplogeomyza Hendel (Helomyzidae): M39 (84-85).
Diploneura Lioy (Phoridae): M110 (329-331).
Diplotoxa Loew (Chloropidae): M38 (434); M74 (248-250); M83 (416-418).
Dipsomyia Bez. (Empididae): M83 (428).
Discocerina Macq. (Ephydridae): M106 (318-321); M112 (197).
Doddiana Curran (Tachinidae): M55 (335); M68 (340-342); M100 (135-139).
Dohrniphora Dahl (Phoridae): M25 (332-334); M110 (329); M111 (31).
Domina Hutt. (Ephydridae): M34 (12).
Drosophila Meig. (Drosophilidae): M12 (613-618); M19 (350-354); M24 (87-88); M35 (2-6); M106 (277) (289) (291 (300-311); M111 (20-22); M112 (193-194).
Duomyia Walk. (Ortalidae): M45 (350-351); M57 (506-511).
Ectinorrhynchus Macq. (Therevidae): M90 (241).
Efftayloria Mall. (Tachinidae): M134 (64).
Egle R.-D. (Muscidae): M23 (38); M30 (48).
Elaphomyia Saunders (Phytalmiidae): M122 (180).
Elassogaster Big. (Ortalidae): M45 (351-352); M82 (22); M121 (115-117); M129 (68-70).
Elliponeura Loew (Chloropidae): M83 (415).
Engycera Mall. (Tachinidae): M119 (180-182).
Emicoptera Macq. (Trypetidae): M124 (441); M127 (239).
Emicopterina Mall. (Trypetidae): M124 (439); M127 (241).
Ensina R.-D. (Trypetidae): M124 (463).
Ephydra Fall. (Ephydridae): M25 (329); M34 (7-9).
Ephydroscinis Mall. (Chloropidae): M18 (331-332); M38 (437); M78 (60); M128 (274).
Ephygrobia Sch. (Ephydridae): M34 (12).
Epicerella Macq. (Pyrgotidae): M53 (10-15) and (24-28).
Epicerina Mall. (Pyrgotidae): M120 (52-53).
Eristalis Latr. (Syrphidae): M7 (227).
Erythronychia B. & B. (Tachinidae): M97 (442-449); M119 (189).
Euamphibolia Town. (Tachinidae): M46 (615).
Eucompsomyia Mall. (Calliphoridae): M36 (325-326).
Euhippelates Mall. (Chloropidae): M24 (96-97); M38 (436); M128 (267).
Eulimnia Town. & Mall. (Sciomyzidae): M48 (172-173).
Eumorphomyia Hendel (Pyrgotidae): M53 (3).
Euphasia Town. (Tachinidae): M68 (326-327).
Euphranta Loew (Trypetidae): M124 (443); M126 (252).
Euphomosia Mall. (Calliphoridae): M36 (324); M107 (12-16).
Euprosopia Macq. (Ortalidae): M45 (344-347); M46 (612); M57 (512-513); M69 (429-431); M82 (7-8); M121 (147-153); M129 (78-88).
Eupsilopa Mall. (Ephydridae): M106 (316-317).
Euryomma Stein (Muscidae): M17 (146).
Eustacomyia Mall. (Tachinidae): M37 (337-338); M67 (133-134).
Euthera Loew (Tachinidae): M55 (333).
Euthyplatystoma Hendel (Ortalidae) (Otitidae): M121 (153).
Eutricimba Mall. (Chloropidae): M83 (408-409).
Euxesta Loew (Ortalidae, Otitidae): M73 (216); M96 (206-210).
Euxestomoea Hendel (Ortalidae) (Otitidae): M121 (106).
Evibrissa Rond. (Tachinidae): M83 (386-388).
Exechopalpus Macq. (Tachinidae): M67 (130-133).
Exorista Meig. (Tachinidae): M55 (330); M119 (182).
Exsul Hutt. (Muscidae): M13 (674).
Fannia R.-D. (Muscidae): M12 (605-606); M58 (156); M72 (305).
Fenwickia Mall. (Helomyzidae): M72 (337-339).
Fergusonina Mall. (Agromyzidae): M18 (337-338); M24 (90-92); M86 (213-216).
Formosia Guer. (Tachinidae): M37 (350-351); M55 (308-312); M67 (104-105).
Formosina Beck. (Chloropidae): M116 (355).
Froggattimyia Town. (Tachinidae): M55 (323); M87 (273-274); M104 (2-7).
Frontalia Mall. (Pyrgotidae): M53 (28-30).
Fucellia R.-D. (Muscidae): M25 (339-340).
Gastrozona Bez. (Trypetidae): M124 (448).
Gaurax Loew (Chloropidae): M19 (355); M38 (444); M96 (217).
Genotrichia Mall. (Tachinidae): M119 (164-165).
Geraldia Mall. (Tachinidae): M68 (327).
Giraffomyia Sharp (Phytalmiidae): M122 (179); M129 (93-98).
Gitonides Knab (Drosophilidae): M19 (349); M35 (7).
Glabellula Bez. (Bombyliidae): M46 (606).
Gonia Meig. (Tachinidae): M55 (323).
Gordonia Mall. (Muscidae): M31 (553-554).
Grammicomyia Big. (Micropezidae): M110 (343-344).
Grapholostylum Macq. (Tachinidae): M37 (352).
Graphomyia R.-D. (Muscidae): M23 (46).
Graphotachina Mall. (Tachinidae): M119 (238-239).
Graptomyza Wied. (Syrphidae): M109 (87).
Griphoneura Sch. (Sapromyzidae): M59 (58); *Ann. Mag. Nat. Hist.*, ser. 9, 16: 362.
Guamomyia Mall. (Otitidae): M135 (206).
Gymnosoma Meig. (Tachinidae): M54 (112).
Gynatoma Collin (Empididae): M83 (426).
Haematobia St. Farg. & Serv. (Muscidae): M39 (506).
Hammatogelma Ender. (Phytalmiidae): M122 (179).
Haplomyza Hendel (Agromyzidae): M104 (1-2).
Hardyia Mall. (Muscidae): M31 (554).
Hecamede Haliday (Ephydridae): M24 (86); M71 (245); M111 (11-12); M112 (197).

Helina R.-D. (Muscidae): M8 (274-275); M9 (137-143); M11 (574); M12 (603-604); M13 (669-672); M17 (142-144); M23 (40-44); M30 (49); M55 (283); M60 (398).
Heliographa Mall. (Muscidae): M29 (508); M58 (167); M60 (399).
Helladepichoria Beck. (Mycetophilidae); M46 (600).
"Heliomyza" (Trypetidae): M124 (464).
Helophilus Leach (Syrphidae): M7 (227).
Helosciomyza Hendel (Sciomyzidae): M7 (228); M24 (81); M44 (324-325); M48 (157-162).
Hemilea Loew (Trypetidae): M81 (265); M124 (447); M126 (269-271).
Hemipyrellia Town. (Calliphoridae): M73 (237).
Hesperodes Coq. (Mycetophilidae): M46 (600).
Heteria Mall. (Tachinidae): M72 (325-331); M119 (205).
Heterodoxa Mall. (Ortalidae) (Otitidae): M96 (212-215).
Heteromeringia Czerny (Clusioididae); M30 (48); M69 (435).
Heteropterna Skuse (Mycetophilidae): M46 (600).
Hexacinia Hendel (Trypetidae): M124 (433); M124 (438-439).
Hexamera B. & B. (Tachinidae): M119 (178).
Hilara Meig. (Empididae): M83 (427).
Hilarempis Bez. (Empididae): M83 (427).
Hillia Mall. (Tachinidae): M55 (328).
Hippelates Loew (Chloropidae): M24 (97); M38 (437-440).
Hirtodrosophila Duda (Drosophilidae): M106 (292-294).
Hobartia Mall. (Tachinidae): M67 (127-128).
Holocnemia Ender. (Ortalidae) (Otitidae): M121 (101).
Homalocnemis Philippi (Empididae): M83 (428); M97 (458).
Homoneura Wulp (Sapromyzidae): M30 (46-47); M31 (551); M35 (12-15); M38 (419-421); M44 (320); M59 (58-82); M61 (412-413); M65 (322-323); M66 (208-210); M98 (35-36); M112 (189); M132 (21-22); M133 (138-144).
Hopkinsella Mall. (Chloropidae): M74 (244).
Hopkinsomyia Mall. (Drosophilidae): M106 (289-291).
Huttonella Ender. (Stratiomyiidae): M45 (362).
Huttonina Tonn. & Mall. (Sciomyzidae): M48 (175-178); M72 (343).
Huttonobesseria Curran (Calliphoridae) (Tachinidae): M44 (329); M83 (385-386).
Huttonomyia Mall. (Helomyzidae): M7 (227); M31 (552); M39 (84).
Huttonophasia Curran (Calliphoridae); M72 (324).
Hyadina Curtis (Ephydridae): M34 (16-17); M111 (15).
Hyalomyia R.-D. (Tachinidae): M54 (109-112); M55 (284); M67 (93-98); M72 (308-309).
Hyalomyodes Town. (Tachinidae): M68 (325).
Hydrellia R.-D. (Ephydridae): M25 (327); M34 (14-15); M111 (14); M112 (197).
Hydrotaea R.-D. (Muscidae): M13 (667-668).
Hylemyia R.-D. (Muscidae): M4 (428-429); M17 (139); M72 (291).
Hyleorus Aldr. (Tachinidae): M55 (334).
Hypaspistomyia Hendel (Agromyzidae) (Milichiidae): M18 (336); M111 (3).
Hypocera Lioy (Phoridae): M2 (433).
Hystricia Macq. (Tachinidae): M97 (431-432).
Hystricina Mall. (Tachinidae): M97 (433-434).
Icasma Collin (Empididae): M83 (428).
Ichneumonosoma de Meij. (Trypetidae): M124 (441).
Ichthyomyia de Meij. (Sapromyzidae): M109 (89-90); M125 (448-449).
Idiella B. & B. (Calliphoridae): M32 (504).
Idiohelina Mall. (Muscidae): M5 (238-239); M26 (141-142); M62 (262-264); M72 (304).
Ilythea Haliday (Ephydridae): M25 (327-8); M112 (197).
Incurviseta Mall. (Sapromyzidae): M25 (324); M38 (402-408).
Isoclusia Mall. (Clusioididae): M66 (200-201).
Kambangania de Meij. (Trypetidae): M124 (445).
Lagarosia Wulp (Trypetidae): M124 (442-443).
Laglaisia Big. (Ortalidae) (Otitidae): M121 (112-113).
Lamprogaster Macq. (Ortalidae): M45 (348-350); M57 (513-516); M69 (432-434); M121 (138-145); M129 (76).
Lamproscatella Hendel (Ephydridae): M111 (7) and (10).
Laphria Meig. (Asilidae): M43 (298); M46 (609).
Laphystia Loew (Asilidae): M43 (297-298).
Lasiocalypter Mall. (Tachinidae): M67 (119-122).
Lasiocalyptrina Mall. (Tachinidae): M67 (122).
Lasionemopoda Duda (Sepsidae): M43 (307).
Lasiopleura Beck. (Chloropidae): M114 (23-25); M128 (268-274).
Lasioxiria Hendel (Ortalidae) (Otitidae): M121 (101).
Lauxania Latr. (Sapromyzidae): M34 (26); M71 (231).
Leiomyza Macq. (Asteiidae): M18 (338).
Leptocera Olivier (Borboridae) (Sphaeroceridae): M44 (326); M106 (324-325); M111 (23-24).
Leucophenga Mik. (Drosophilidae): M12 (613-615); M19 (349-350); M25 (334-335); M35 (2); M109 (90).
Leucopsis Meig. (Ochthiphilidae): M70 (490).
Leucostoma Meig. (Tachinidae): M68 (323-325).
Limnella Mall. (Muscidae): M44 (328).
Limnellia Mall. (Ephydridae): M25 (332).
Limnina Mall. (Muscidae): M44 (327-328).
Limnohelina Mall. (Muscidae): M72 (294-303).
Limnophora R.-D. (Muscidae): M17 (144-145); M22 (327-329); M25 (340); M58 (164-169); M65 (330-333); M95 (198-199); M107 (7).
Limosina Macq. (Borboridae): M1 (236-237).
Linnaemyia R.-D. (Tachinidae): M55 (317).
Liodrosophila Duda (Drosophilidae): M45 (354-355).
Lioscinella Duda (Chloropidae): M134 (41-57).
Lipara Meig. (Chloropidae): M128 (279-280).
Lispa Latr. (Muscidae): M10 (384-389); M12 (606-609); M22 (333-338); M25 (340); M58 (153-155); M60 (391-392).
Lispocephala Pok. (Muscidae): M12 (604-605); M52 (80-81); M60 (392-394).
Lissocephala Mall. (Drosophilidae): M106 (287-289).
Lonchaea Fall. (Lonchaeidae): M43 (306-307); M74 (241-243).
Lonchaegaster White (Stratiomyidae): M45 (366).
Loriomyia Kert. (Ortalidae) (Otitidae): M121 (113).
Loxoneuroides Hendel (Ortalidae) (Otitidae): M121 (101).
Lucilia R.-D. (Calliphoridae): M20 (639); M36 (320-322); M92 (16).
Lyperosia Rond. (Muscidae): M23 (46).
Macquartia R.-D. (Tachinidae): M97 (434-436); M119 (221-223).
Macrocanace Tonn. & Mall. (Ephydridae): M34 (5-6).
Macrochloria Mall. (Tachinidae): M55 (326); M114 (20).
Macropia Mall. (Tachinidae): M68 (322-323); M80 (296).
Macrostyla Lioy (Chloropidae): M128 (265-267).

Madiza Fall. (Chloropidae): M128 (276).
Maenomenus Bez. (Pyrgotidae): M53 (6 and 28).
Maira Sch. (Asilidae): M43 (299).
Mallota Meig. (Syrphidae): M7 (227).
Maorimyia Tonn. & Mall. (Helcomyzidae): M48 (155-156); M103 (325-327).
Maorina Mall. (Opomyzidae): M71 (235-241).
Maquilingia Mall. (Sapromyzidae): M133 (144).
Marquesia Mall. (Drosophilidae): M96 (223); M112 (193).
Masicera Macq. (Tachinidae): M110 (358).
Meachina Ender. (Phytalmiidae): M122 (179).
Medina R.-D. (Tachinidae): M110 (362-364).
Medinella Mall. (Tachinidae): M119 (235-237).
Megaselia Lioy (Phoridae): M110 (333-338); M111 (31).
Melanagromyza Hendel (Agromyzidae): M111 (19).
Melanina Mall. (Sapromyzidae): M38 (413); M109 (89).
Melanochelia Rond. (Muscidae): M13 (673).
Melanum Beck. (Chloropidae): M83 (418-419); M116 (352-353).
Melina R.-D. (Sciomyzidae): M44 (325).
Melinda R.-D. (Calliphoridae): M44 (328-329); M114 (22-23).
Merodonta Mall. (Chloropidae): M128 (263-264).
Mesembriomintho Town. (Tachinidae): M55 (315).
Mesoctenia Ender. (Ortalidae) (Otitidae): M121 (123).
Metalaphria Ric. (Asilidae): M46 (608).
Metallea Wulp (Calliphoridae): M36 (329-331); M55 (283).
Metaphagia Coq. (Tachinidae): M119 (168).
Metopomyia Mall. (Muscidae): M8 (272-273); M12 (603).
Metaponia Macq. (Stratiomyiidae): M45 (365).
Metopobranchia Ender. (Micropezidae): M110 (346).
Microcalliphora Town. (Calliphoridae): M36 (326).
Microdon Meig. (Syrphidae): M1 (233-236).
Microepicausta Hendel (Ortalidae) (Otitidae): M121 (99).
Microhystricia Mall. (Tachinidae): M119 (177-178).
Microneurum Beck. (Chloropidae): M96 (216).
Microtropeza Macq. (Tachinidae): M46 (614-615); M55 (287-288); M67 (99-101).
Milichia Meig. (Agromyzidae) (Milichiidae): M31 (546-547).
Milichiella Giglio-Tos (Agromyzidae) (Milichiidae): M18 (336); M78 (76-78); M106 (326); M111 (3).
Millerina Mall. (Muscidae): M26 (139-141); M72 (292-294).
Miltogramma Meig. (Calliphoridae): M36 (335); M69 (440-443).
Minettia R.-D. (Sapromyzidae): M61 (413); M132 (20-21); M133 (144).
Monocera Wulp (Sapromyzidae): M61 (410); M133 (135).
Morellia R.-D. (Muscidae): M60 (408).
Mosillus Latr. (Ephydridae): M111 (13-14); M112 (197).
Musca Linné (Muscidae): M58 (174); M72 (305); M95 (203).
Muscina R.-D. (Muscidae): M12 (601); M72 (306).
Mycodrosophila Oldenberg (Drosophilidae): M35 (1); M76 (331-332); M106 (284-287); M111 (20); M112 (193).
Myiospila Rond. (Muscidae): M5 (237-238); M22 (330-331).
Myothyria Wulp (Tachinidae): M68 (338-340).
Naupoda O.S. (Ortalidae) (Otitidae): M57 (513); M121 (122); M129 (75).
Neactina Ender. (Stratiomyiidae): M45 (362).
Nemorea R.-D. (Tachinidae): M55 (339); M97 (431).
Neoamenia Mall. (Tachinidae): M67 (103).
Neoerythronychia Mall. (Tachinidae): M97 (450-451)
Neoeuxesta Mall. (Ortalidae): M73 (218); M96 (207).
Neoexaireta O.S. (Stratiomyiidae): M45 (361-362).
Neohelina Mall. (Muscidae): M21 (415); M22 (329-330).
Neohemigaster Mall. (Ortalidae) (Otitidae): M121 (127).
Neohydrellia Mall. (Ephydridae): M111 (14-15); M112 (197).
Neolimnia Tonn. & Mall. (Sciomyzidae): M48 (163-171).
Neomedina Mall. (Tachinidae): M110 (362-364).
Neoplatyura Mall. (Mycetophilidae): M46 (601).
Neosaropogon Ric. (Asilidae): M43 (300).
Neoscatella Mall. (Ephydridae): M111 (9-10); M112 (200).
Neoscotia = *Thrycolyga* Town. (Tachinidae): M55 (332).
Neosophira Hendel (Trypetidae): M124 (414).
Neotachina Mall. (Tachinidae): M119 (207); M119 (241-242).
Neothemara Mall. (Trypetidae): M124 (433-434); M126 (253-255).
Neotoxura Mall. (Pyrgotidae): M53 (23-24).
Neotryphera Mall. (Tachinidae): M119 (218-219).
Nervijuncta Marshall (Mycetophilidae): M46 (600).
Nicholsonia Mall. (Pyrgotidae): M53 (31).
Nocticanace Mall. (Ephydridae): M111 (4-5); M112 (196-197).
Nothoasteia Mall. (Asteiidae): M115 (259-269).
Notiphila Fall. (Ephydridae): M25 (326-327).
Notonaulax Beck. (Chloropidae): M83 (409).
Notospila O.S. (Ortalidae) (Otitidae): M121 (145).
Nusa Walk. (Asilidae): M43 (298).
Occisor Hutt. (Tachinidae): M119 (206-207).
Ochromeigenia Town. (Tachinidae): M37 (337).
Ochthiphila Fall. (Ochthiphilidae) (Ephydridae): M34 (5-6); M70 (491).
Ocnerus Costa (Trypetidae): M124 (447).
Oecothea Hall. (Helomyzidae): M39 (86); M103 (184).
Oedaspis Loew (Trypetidae): M124 (451-452).
Oedaspoides Hendel (Trypetidae): M124 (452).
Ommatius Wied. (Asilidae): M56 (408-410).
Onesia R.-D. (Calliphoridae): M84 (68).
Ophyra R.-D. (Muscidae): M13 (666); M58 (169-170); M60 (399); M65 (333); M95 (198-197).
Opsidiopsis Town. (Calliphoridae): M69 (439-440).
Orchisia Rond. (Muscidae): M58 (157).
Ortaloptera Edwards (Trypetidae): M124 (454).
Orthellia R.-D. (Muscidae): M15 (513-514); M23 (45-46); M60 (408); M62 (264); M107 (8-9).
Oscinella Beck. (Chloropidae): M128 (287-288).
Oscinelloides Mall. (Chloropidae): M128 (267-268).
Oscinis Latr. (Chloropidae): M116 (337-351).
Oscinosoma Lioy (Chloropidae): M74 (247-248); M78 (60-66); M83 (407 and 411-414); M96 (217); M111 (30).
Oxysarcodexia Town. (Calliphoridae): M92 (14).
Pachygaster Meig. (Stratiomyiidae): M45 (366).
Pachylophus Loew (Chloropidae): M24 (95); M38 (429).

Pachymeres Greene (Bombyliidae): M16 (205); M46 (606); M51 (138-140).
Pachyophthalmus B. & B. (Calliphoridae): M69 (439).
Palia Curran (Tachinidae): M55 (335).
Paliana Curran (Tachinidae): M55 (335); M68 (344).
Palpostoma R.-D. (Tachinidae): M37 (339); M67 (135); M80 (296-297).
Panurgopsis Kert. (Sapromyzidae): M66 (211-212).
Paracoenosia Mall. (Muscidae): M119 (254-256).
Paraeuxesta Coq. (Ortalidae): M96 (207).
Parahippelates Beck. (Chloropidae): M12 (620-621); M18 (329-331); M24 (96); M38 (437); M43 (302-303).
Parahyadina Tonn. & Mall. (Ephydridae): M34 (17).
Paralauxania Hendel (Sapromyzidae): M30 (32-33); M38 (410-412); M42 (163).
Paralimna Loew (Ephydridae): M25 (325-326); M31 (545-546); M106 (313); M111 (11); M112 (197).
Paramenia B. & B. (Tachinidae): M44 (330); M46 (614).
Paramphibolia B. & B. (Tachinidae): M55 (312-313).
Paranomina Hendel (Sapromyzidae): M38 (402).
Paratricyclea Ville (Calliphoridae): M36 (523).
Paratrirhithrum Shiraki (Trypetidae): M124 (465).
Paropsivora Mall. (Tachinidae): M104 (7-8).
Paroxyna Hendel (Trypetidae): M112 (200); M118 (115-116); M124 (463); M126 (228).
Pawrothrix Bez. (Calliphoridae): M44 (329); M73 (235-236).
Parydra Stenhammar (Ephydridae): M34 (9).
Passeromyia Ville (Muscidae): M23 (46).
Pectiniseta Stein (Muscidae): M58 (163); M65 (326-328).
Pemphigonotus Lamb (Chloropidae): M116 (354).
Peremptor Hutt. (Tachinidae): M55 (343); M97 (436) (452-454); M119 (205).
Pericoma Walk. (Psychodidae): M3 (265).
Perissoneura Mall. (Ortalidae): M96 (207-208).
Peronia R.-D. (Muscidae): M31 (554).
Perrissina Mall. (Tachinidae): M119 (184-187).
Petenia B. & B. (Tachinidae): M119 (205).
Phagocarpus Rond. (Trypetidae): M124 (448); M127 (241).
Phania Meig. (Tachinidae): M83 (385-386).
Phaonia R.-D. (Muscidae): M6 (414-415); M17 (141-142).
Phaoniella Mall. (Tachinidae): M119 (217).
Philygriola Hendel (Ephydridae): M111 (15-16); M112 (197).
Phlebotomus Agassiz (Psychodidae): M3 (265).
Phora Latr. (Phoridae): M110 (334).
Phorocera R.-D. (Tachinidae): M55 (329-330); M119 (196).
Phorocerosoma Mall. (Tachinidae): M55 (327); M68 (326).
Phorocerostoma Mall. (Tachinidae): M68 (326).
Phumosia R.-D. (Calliphoridae): M107 (18).
Phytalmia Gerst. (Phytalmiidae): M122 (170-174); M129 (90).
Phytomyza Fall. (Agromyzidae): M12 (622); M110 (341-342).
Pilimyia Mall. (Tachinidae): M68 (329-330).
Pilinasica Mall. (Syrphidae): M7 (227).
Piophila Fall. (Piophilidae): M25 (316); M35 (8); M74 (251); M80 (292); M96 (215); M103 (246).
Plagiomyia Curran (Tachinidae): M119 (169-171).
Plagiostenopterina Hendel (Ortalidae): M45 (353); M73 (229-330); M82 (15); M131 (114-115); M129 (68).
Plagiprospherysa Town. (Tachinidae): M68 (320).
Plastophora Brues (Phoridae): M2 (501).
Platensina Ender. (Trypetidae): M124 (458-459); M126 (277).
Platyina Mall. (Chloropidae): M38 (436); M128 (267).
Platyroptilon Westwood (Mycetophilidae): M46 (600).
Platytachina Mall. (Tachinidae): M119 (211-216).
Platyura Meig. (Mycetophilidae): M46 (600).
Plecia Weid. (Bibionidae): M46 (602-606).
Plethochaetigera Mall. (Tachinidae): M119 (192-196).
Podanema Mall. (Sepsidae): M43 (308).
Podotachina = *Thrycolyga* (Tachinidae): M55 (332).
Poecilohetaerella Tonn. & Mall. (Sapromyzidae): M34 (25-26); M38 (408); M42 (162).
Poecilohetaerus Hendel (Sapromyzidae): M24 (84-85); M34 (23-24); M38 (408).
Pogonortalis Hendel (Ortalidae): M46 (611-612); M69 (429); M121 (120).
Pollenia R.-D. (Calliphoridae): M20 (639); M36 (318-319); M72 (318-323); M114 (21-22).
Polyara Walk. (Trypetidae): M124 (418).
Polytocus Lamb (Sciomyzidae): M48 (156-157).
Prionoscelus Beck. (Chloropidae): M114 (25-26).
Prochaetops Bez. (Sapromyzidae): M91 (3-12); M112 (182-187).
Procissio Hutt. (Tachinidae): M97 (451-452); M119 (201-205).
Prodalmannia Bez. (Pyrgotidae): M53 (18-20 and 30).
Prodiaphania Town. (Tachinidae): M37 (351-352); M55 (291-292).
Prohippelates Mall. (Chloropidae): M74 (245); M96 (216); M134 (64).
Promachus Loew (Asilidae): M46 (610).
Prosena St. Farg. & Serv. (Tachinidae): M55 (315); M67 (111-116); M80 (298); M85 (127-132); M107 (24); M110 (365); M119 (190).
Prosenina Mall. (Tachinidae): M67 (116-117).
Prosenosoma Mall. (Tachinidae): M119 (189-190).
Prosochaeta Mall. (Sciomyzidae): M113 (95-96).
Prosopantrum Ender. (Helomyzidae): M103 (200-202).
Protephritis Shiraki (Trypetidae): M124 (459).
Protoborborus Mall. (Borboridae): M102 (261-262)
Protocoelopa Mall. (Coelopidae): M101 (346-347).
Protohystricia Mall. (Tachinidae): M55 (341-342); M68 (352-353); M97 (431-433); M119 (178).
Protomeigenia Town. (Tachinidae): M55 (323).
Protomiltogramma Town. (Calliphoridae): M36 (335); M69 (444-447).
Pseudacanthoneura Mall. (Trypetidae): M124 (434-435).
Pseudepicausta Hendel (Ortalidae): M82 (27-28); M121 (118-119); M129 (71).
Pseudeuxesta Hendel (Ortalidae): M96 (209); M121 (98); M129 (67).
Pseudina Mall. (Trypetidae): M124 (446-447).
Pseudocleitamia Mall. (Ortalidae): M121 (105).
Pseudodiopsis Hendel (Diopsidae): M117 (437-438).
Pseudoformosina Mall. (Chloropidae): M116 (355-356); M134 (64).
Pseudoleria Garrett (Helomyzidae): M31 (551-552); M39 (86); M103 (183).
Pseudoleucopis Mall. (Agromyzidae) (Ochthiphilidae) (Sciomyzidae): M24 (93); M25 (335); M70 (489-490); M130 (266).
Pseudonapomyza Hendel (Agromyzidae): M110 (341).
Pseudoplatyura Skuse (Mycetophilidae): M46 (600).
Pseudorichardia Hendel (Ortalidae): M63 (100); M73 (222); M96 (206).

Pseudosophira Mall. (Trypetidae): M124 (415).
Pseudospheniscus Hendel (Trypetidae): M124 (450-451); M126 (267-269); M127 (241-242).
Pseudotrichopoda Mall. (Tachinidae): M99 (77-79).
Psiloya Fall. (Ephydridae): M34 (12); M106 (314-315).
Psychoda Latr. (Psychodidae): M3 (265).
Pterogenia Big. (Ortalidae): M57 (513); M121 (126).
Ptilona Wulp (Trypetidae): M124 (464).
Ptilonesia Bez. (Calliphoridae): M36 (303); M72 (316).
Ptilophyllodromia Bez. (Empididae): M69 (450); M83 (428).
Ptiolina Wulp (Trypetidae): M124 (419) (431) (441).
Puliciphora Dahl. (Phoridae): M110 (339).
Pygidia Mall. (Tachinidae): M68 (330-332).
Pygophora Sch. (Muscidae): M5 (239); M10 (381-383); M58 (160-162); M60 (394-396); M108 (77).
Pyrellia R.-D. (Muscidae): M23 (46).
Quadra Mall. (Tachinidae): M55 (320); M68 (342-343).
Rabaulia Mall. (Trypetidae): M126 (257-258); M124 (422).
Rainieria Rond. (Micropezidae): M110 (345).
Rhabdochaeta de Meij. (Trypetidae): M124 (463); M126 (228).
Rhagadolyra Hendel (Sapromyzidae): M38 (413).
Rhagoletis Loew (Trypetidae): M124 (452).
Rhamphella Mall. (Empididae): M69 (449).
Rhamphomyia Meig. (Empididae): M69 (450); M83 (425-426).
Rhicnoessa Loew (Tethinidae) (Agromyzidae): M111 (18).
Rhinia R.-D. (Calliphoridae): M32 (504); M36 (332); M46 (612).
Rhinomyiobia B. & B. (Tachinidae): M55 (316); M67 (129-130); M110 (365).
Rhyncodexia Big. (Tachinidae): M67 (119).
Rhyncomydaea Mall. (Muscidae): M9 (135); M12 (604); M23 (40); M30 (48-49); M31 (554).
Rhytidortalis Hendel (Ortalidae) (Otitidae): M121 (106).
Richardia R.-D. (Ortalidae): M96 (206).
Rioxa Walk. (Trypetidae): M124 (435-436); M124 (464).
Rioxoptilona Hendel (Trypetidae): M124 (436-437).
Rivellia R.-D. (Ortalidae): M45 (351); M63 (100); M70 (491-492); M73 (219-221); M121 (120-121); M129 (71-72); M131 (19).
Rosenwaldia Mall. (Drosophilidae): M112 (195-196).
Rutilia R.-D. (Tachinidae): M37 (346-349); M44 (331-335); M55 (293-307); M67 (107-109); M78 (78); M110 (349-351); M114 (15-18).
Rutilodexia Towns. (Tachinidae): M37 (352).
Samoaia Mall. (Drosophilidae): M106 (271-278).
Sapromyza Fall. (Sapromyzidae): M24 (83-84); M25 (316-319); M30 (33-46); M34 (21-23); M35 (8-12); M38 (414-418); M45 (355-360); M61 (413-414); M69 (434); M109 (87-89).
Sapromyzosoma Mall. (Sapromyzidae): M24 (83); M25 (320-322).
Sarcophaga Meig. (Calliphoridae): M62 (269-272); M64 (256-257); M75 (481-483); M92 (13-14); M107 (21-22); M110 (365); M119 (190).
Saropogon Loew (Asilidae): M43 (300).
Scaptomyza Hardy (Drosophilidae): M12 (618-619); M96 (219-222); M106 (295-298); M111 (22-23); M112 (194-195).
Scaptomyzella Hendel (Drosophilidae): M96 (220-221).
Scaptomyzetta Hendel (Drosophilidae): M96 (220-221).
Scatella R.-D. (Ephydridae): M25 (329-331); M34 (10-12); M111 (7-9); M112 (200).
Scatophila Beck. (Ephydridae): M111 (10).
Scholastes Loew (Ortalidae): M63 (99); M73 (222-223); M96 (205-206); M98 (36); M121 (128-130); M129 (72-75); M131 (20); M135 (207-208).
Scoliophthalmus Beck. (Chloropidae): M78 (67).
Scotinosoma Loew (Ortalidae): M121 (117-118).
Semisutura Mall. (Tachinidae): M37 (339-342); M55 (332).
Senostoma Macq. (Tachinidae): M46 (616-617); M114 (10-15).
Sepedon Latr. (Sciomyzidae): M44 (322-323).
Sepsis Fall. (Sepsidae): M25 (312-314).
Sigaloessa Loew (Asteiidae): M38 (445-446); M76 (321-322).
Siphunculina Rond. (Chloropidae): M19 (358-359); M38 (436); M128 (267).
Sophira Walk. (Trypetidae): M124 (430-431 and 464); M126 (255-257).
Spaniopsis White (Rhagionidae): M79 (274-275).
Spathulina Rond. (Trypetidae): M81 (266); M124 (456-457); M135 (202).
Sphaericocephala Czerny (Micropezidae): M110 (343).
Sphaerocera Latr. (Borboridae): M24 (85).
Sphenella R.-D. (Trypetidae): M124 (459-460).
Spheniscomyia Bez. (Trypetidae): M124 (450); M126 (273).
Spilogona Schnabl & Dziedzicki (Muscidae): M83 (379-383).
Spinulophila Duda (Drosophilidae): M106 (311).
Stawella Bez. (Trypetidae): M124 (443).
Steganopsis de Meij. (Sapromyzidae): M24 (81-82); M31 (548-549); M61 (409-410); M133 (132-133).
Stenomicra Coq. (Asteiidae): M40 (25).
Stenopogon Loew (Asilidae): M46 (607).
Stilbomyella Mall. (Tachinidae): M108 (74-76).
Stilbomyia Macq. (Tachinidae): M37 (344-345); M67 (102-103).
Stomatomyia B. & B. (Tachinidae): M68 (320-321).
Stomatorhinia Rond. (Calliphoridae): M36 (333-334).
Stomosis Melander (Agromyzidae) (Milichiidae): M24 (88-89).
Stomoxys Geoff. (Muscidae): M58 (175); M89 (402-403).
Strongygaster Macq. (Tachinidae): M67 (92-93).
Sturmia R.-D. (Tachinidae): M55 (330-331); M68 (351-352); M110 (353-358).
Sumpigaster Macq. (Tachinidae): M67 (110).
Synthesiomyia B. & B. (Muscidae): M23 (46); M58 (174).
Syrphus Fabr. (Syrphidae): M7 (227).
Tachina Meig. (Tachinidae): M97 (431-434); M119 (243-244).
Taeniomyia Stein (Muscidae): M60 (390).
Tanypoda Rond. (Micropezidae): M110 (345).
Tapeigaster Macq. (Neottiophilidae): M31 (553); M35 (16); M69 (435-436); M86 (217); M109 (94-95).
Tasmania = Lauxania (Sapromyzidae): M34 (26); M71 (231).
Taylorina Mall. (Tachinidae): M67 (98-99).
Telostylinus Ender. (Neriidae): M110 (343).
Tephrella Bez. (Trypetidae): M124 (450) (456); M126 (272).
Tephritis Latr. (Trypetidae): M83 (391-396); M124 (456-457) (459) (460-462).
Teratomyza Mall. (Anthomyzidae): M102 (113-114).
Termitoriosa Hendel (Trypetidae): M124 (436).
Tetanocera Latr. (Sciomyzidae): M7 (228).
Tethina Hal. (Agromyzidae) (Tethinidae): M18 (337); M109 (91-93)); M111 (17).
Tethinosoma Mall. (Helomyzidae): M72 (335-336).
Thelairia R.-D. (Tachinidae): M67 (110).
Themara Walk. (Trypetidae): M124 (419).
Themarohystrix Hendel (Trypetidae): M124 (422-423).

Themaroides Hendel (Trypetidae): M124 (419) (464).
Thereutria Loew (Asilidae): M46 (608).
Thrycolyga Rond. (Tachinidae): M55 (331-332).
Thyridula Beck. (Chloropidae): M19 (358); M24 (96); M31 (546); M38 (441-442); M128 (274-275).
Tomoioria Mall. (Clusioididae): M63 (99); M96 (215); M135 (209).
Toxopoda Macq. (Sepsidae): M46 (611).
Toxura Macq. (Pyrgotidae): M53 (6-9 and 24).
Tricimba Lioy (Chloropidae): M19 (356-357); M25 (337-338); M38 (442-444); M83 (409-410); M111 (29-30); M128 (277).
Trigonometopsis Mall. (Sapromyzidae): M24 (82-83); M38 (412); M59 (35 and 37).
Trigonometopus Macq. (Sapromyzidae): M31 (550-551); M44 (319-320); M59 (34); M66 (212-213); M112 (188).
Tritaxys Macq. (Tachinidae): M54 (113-114).
Truphia Mall. (Tachinidae): M72 (310-311).
Trypanea Schrank (Trypetidae): M83 (398-404); M94 (146-147); M124 (462-463).
Trypaneoides Tonn. & Mall. (Sapromyzidae): M34 (20); M38 (418-419); M44 (321-322); M61 (411); M66 (203-206); M71 (244); M133 (145).
Trypanocentra Hendel (Trypetidae): M124 (428-430).
Trypeta Meig. (Trypetidae): M124 (451) (459-460) (462-464).
Typhera Meig. (Tachinidae): M119 (219).
Typherina Mall. (Tachinidae): M119 (219-220).
Uclesiella Mall. (Tachinidae): M119 (167-168).
Uprohmyia Mall. (Drosophilidae): M106 (280-283).
Urellia R.-D. (Trypetidae): M124 (462).
Urophora R.-D. (Trypetidae): M124 (450) (466).
Veluta Mall. (Tachinidae): M119 (207-208).
Vespivora Mall. (Tachinidae): M68 (347).
Viviparomusca Town. (Muscidae): M23 (45-46).
Voria R.-D. (Tachinidae): M68 (318-319).
Voriella Mall. (Tachinidae): M68 (335-337); M80 (298); M110 (361-362).
Vorina Mall. (Tachinidae): M68 (321-322).
Waterhouseia Mall. (Anthomyzidae): M115 (260-261).
Wattia Mall. (Tachinidae): M119 (162-164).
Winthemia R.-D. (Tachinidae): M55 (332); M68 (348-349); M110 (358-359).
Xanthocanace Hendel (Ephydridae): M18 (334).
Xanthotrypeta Mall. (Trypetidae): M124 (444); M126 (250-251).
Xarnula Walk. (Trypetidae): M124 (440); M126 (261-263).
Xeneura Mall. (Helomyzidae): M72 (339).
Xenocalliphora Mall. (Calliphoridae): M20 (639); M72 (317-318).
Xenognathus Mall. (Ortalidae): M73 (226-228).
Xenolispa Mall. (Muscidae): M8 (280); M10 (384); M12 (609-611).
Xenoplatyura Mall. (Mycetophilidae): M46 (601-602).
Xenorhynchia Mall. (Tachinidae): M119 (190-191).
Xenosciomyza Tonn. & Mall. (Sciomyzidae): M48 (162-163).
Xenosepsis Mall. (Sepsidae): M25 (315).
Xenosina Mall. (Muscidae): M60 (399).
Zealandortalis Mall. (Ortalidae): M71 (243-244).
Zealandotachina Mall. (Tachinidae): M119 (226-234).
Zebromyia Mall. (Tachinidae): M55 (321).
Zenillia R.-D. (Tachinidae): M55 (331).
Zita Curan (Tachinidae): M55 (335); M68 (330).
Zosteromeigenia Town. (Tachinidae): M55 (315).
Zosteromyia B. & B. (Tachinidae): M67 (110-111).
Zygaenula Dol. (Ortalidae): M121 (123).
Zygothrica Wied. (Drosophilidae): M106 (278-279).

7. List of Subgenera and Subgeneric Groups with Cross References to the Bibliography.

Acanthophila (Drosophila): M106 (311).
Actia (Actia): M68 (306-310).
Adantineura (Antineura): M121 (104).
Allophylella (Allophylopsis): M39 (90-91).
Allophylopsis (Allophylopsis): M39 (94-99).
Aprochaetops (Prochaetops): M112 (181-183).
Bactrocera (Dacus): M81 (259); M124 (412).
Callantra (Dacus): M124 (411-412).
Calosia (Zealandotachina): M119 (233-234).
Carpolonchaea (Lonchaea): M74 (241-243).
Ceratopelta (Lamprogaster): M121 (140-141).
Chaetodacus (Dacus): M124 (413); M118 (111-113).
Chaetopletha (Plethochaetigera): M119 (195-196).
Clusiosomina (Clusiosoma): M124 (426-427).
Collinella (Leptocera): M44 (326).
Coprophila (Leptocera): M111 (23-24).
Crapitula (Plecia): M46 (602-603).
Dirioxa (Rioxa): M124 (435-436).
Drosophila (Drosophila): M111 (21-22); M112 (193).
Duomyia (Duomyia): M57 (507-511).
Ephydrella (Ephydra): M34 (7-9).
Euhomoneura (Homoneura): M38 (419); M59 (65).
Euthyridula (Thyridula): M38 (441); M128 (274).
Fucomyia (Coelopa): M101 (345).
Griphoneuroides (Homoneura): M59 (58).
Haematobia (Haematobia): M89 (506).
Helicobia (Sarcophaga): M110 (365).
Hemipyrellia (Lucilia): M36 (320-321).
Hendelomyza (Sapromyza): M35 (8-9).
Homoneura (Homoneura): M38 (420-421); M44 (320); M59 (68-80); M65 (322-323); M66 (208-209); M132 (22); M133 (139-144).
Huttonella (Huttonina): M48 (178).
Huttonina (Huttonina): M48 (174-178); M72 (342).
Lamprogaster (Lamprogaster): M121 (141-145).
Lamprolonchaea (Lonchaea): M74 (241).
Lasiopleura (Lasiopleura): M128 (270-274).
Liolamprogaster (Lamprogaster): M121 (141).
Liriomyza (Agromyza): M38 (426-428).
Lucilia (Lucilia): M36 (321-322).
Macrotethina (Tethina): M109 (91-92).
Marquesodacus (Dacus): M94 (145-146).
Melanagromyza (Agromyza): M38 (424-426); M110 (340).
Microrutilia (Rutilia): M114 (18).
Minettioides (Homoneura): M66 (209-210).
Neocalobata (Calobata): M110 (346-348).
Neolimnia (Neolimnia): M48 (165-170).
Neorutilia (Rutilia): M114 (17).
Neoscleropogon (Stenopogon): M46 (607).
Neosepedon (Dichaetophora): M44 (323-324).
Neotachina (Neotachina): M119 (241-243).
Neotrigonometopus (Trigonometopus): M44 (319-320); M59 (34).
Ophiomyia (Agromyza): M38 (426).
Paradrosophila (Drosophila): M106 (277-278).
Paraphylopsis (Allophylopsis): M39 (93-94).
Phenicia (Lucilia): M36 (321).
Philpottomyia (Allophylopsis): M39 (92).
Plagiostenopterina (Plagiostenopterina): M82 (15); M121 (114).

Plecia (Plecia): M46 (603-606).
Poecilosomella (Leptocera): M111 (23).
Prochaetops (Prochaetops): M91 (3-11); M112 (183-187).
Prochaetopsis (Prochaetops): M91 (11-12); M112 (187).
Pseudolimnia (Neolimnia): M48 (171).
Rutilia (Rutilia): M110 (249-351).
Schizoceromyia (Actia): M68 (304-305).
Scotophilella (Leptocera): M111 (23-24).
Senostoma (Rutilia): M46 (616); M55 (305-307); M67 (109).
Separata (Euprosopia): M82 (8).
Sepimentum (Pollenia): M36 (318-319).
Solomonia (Homoneura): M133 (138-139).
Spinulophila (Drosophila): M106 (311); M111 (20-21); M112 (193).
Stenopterosoma (Plagiostenopterina): M121 (114-115).
Tachineo (Neotachina): M119 (243-244).
Talaractia (Actia): M68 (306).
Tenuicornis (Euprosopia): M82 (7).
Terraeregina (Parahippelates): M43 (303); M128 (270).
Tethina (Tethina): M109 (92-93).
Thyridula (Thyridula): M128 (274-275).
Xenocalliphora (Calliphora): M46 (613).
Xenohomoneura (Homoneura): M38 (419-420).
Zeugodacus (Dacus): M124 (412).

8. List of Species with Cross References to the Bibliography and Details of Present Location of Types and Known Identified Material.

Species and References.	*Holotype.*	*Allotype.*	*Paratypes.*	*Determined Specimens. Number of Specimens, by whom determined, and location.*
abbreviata (Mall.) (*Cadrema*): M128(278)				
abbreviata Mall. (*Hippelates*): M38(440)	CSIRO			
abdominalis R.-D. (*Phumosia*): M107(18)				
aberrans Mall. (*Sapromyza*): M25(317)	SPHTM			
**abrupta* Tonn. & Mall. (*Huttonina*): M48(175); M72(343)			1 USNM	1 Malloch USNM
†*accepta* Mall. (*Calliphora*): M36(316–317) ..	USNM	SPHTM	1 SPHTM; 3 USNM	1 Malloch SPHTM
achaeta Mall. (*Helina*): M9(143); M23(43) ..	BM (NH)			2 Malloch USNM
achaeta Mall. (*Plagiomyia*): M119(170)	Cawthron			
acidiomorpha Hendel (*Acanthoneura*): M124(432)..				2 Malloch, 1 Taylor SPHTM
acroleuca (Sch.) (*Spathulina*): M81(266); M124(456–457); M135(202)				3 Malloch Bishop M; 14 Malloch USNM
acroleuca Sch. (*Tephritis*): M124(456–457)				
acrostichalis Mall. (*Ephydra*): M25(329)	SPHTM	SPHTM		3 Wirth USNM
acrostichalis (de Meij.) (*Homoneura*): M66(207); M133(143)				2 Malloch SPHTM
acuminata Rond. (*Plagiprospherysa*): M68(320)				2 Malloch SPHTM
acuticornis Stein (*Coenosia*): M22(332)				2 Malloch USNM
acuticornis Hendel (*Oedaspoides*): M124(452)				
acuticornis Loew (*Phytomyza*): M110(341–342)				
adamsoni Mall. (*Prochaetops*): M91(7); M112(181)	Bishop M		1 USNM	
adamsoni Mall. (*Tricimba*): M111(29–30) ..	Bishop M			
addens (Walk.) (*Conicipethea*): M121(103)				
addita Walk. (*Helina*): M9(141); M23(42) ..				1 Malloch SPHTM; 19 Malloch USNM
adelensis (Miller) (*Homalocnemis*): M97(458) ..				2 Malloch USNM
adspersa Coq. (*Tephritis*): M124(460)				
advena Mall. (*Chloromerus*): M116(336–337) ..	SPHTM		1 SPHTM	
adversa Mall. (*Helina*): M23(42); M23(44) ..	SPHTM			
aenea (Fabr.) (*Chrysomyza*): M24(85); M73(215); M129(67); M135(205)				2 Aldrich, 1 Hardy SPHTM; 2 Malloch Bishop M
aenea (Fabr.) (*Maira*): M43(299)				
aenea (Wied.) (*Plagiostenopterina*): M45(353); M73(229); M121(114)				2 Malloch, 1 Hill SPHTM; 1 Malloch USNM
aeneiventris Mall. (*Helina*): M9(143); M23(43) ..	BM (NH)	BM (NH)	2 BM (NH)	
aenescens Mall. (*Melanina*): M38(413)				
aenescens Wied. (*Ophyra*): M58(170)				
aenigmaticus Mall. (*Dacus*): M81(261)	BM (NH)			
aequalis Mall. (*Adapsila*): M120(51–52)	BM (NH)			
aequalis Walk. (*Chrysopilus*): M79(276)				
aequalis Coq. (*Dacus*): M124(411); M126(230)				
aequalis (Beck.) (*Lasiopleura*): M18(331); M128(272)				1 Malloch SPHTM; 3 Malloch Sabrosky Coll.
aequalis Beck. (*Parahippelates*): M18(331)				
aequalis Mall. (*Sturmia*): M110(355–356)	Bishop M			
affinis Tonn. & Mall. (*Clasiopa*): M34(13) ..	C'bury M			
‡*affinis* Mall. (*Incurviseta*): M38(404)	SPHTM		2 USNM	
affinis Hendel (*Rivellia*): M121(121)				
agilis Mall. (*Oscinosoma*): M74(247)	Bishop M		1 BM (NH)	
aitapensis Mall. (*Scholastes*): M121(128–129); M129(74); M131(20); M135(207–208)	SPHTM	BM (NH)	3 USNM; 1 BM (NH)	
albertisi Ost.-Sack. (*Achias*): M121(137)				

* The identified specimen in USNM is from Nelson, Feb. 1928. It has also a blue paratype label but is not cited in the original description.

† Locality of allotype is Sydney, and of paratype is Collaroy, which is not in agreement with the types mentioned in the original description.

‡ A paratype in USNM from Victoria says W. F. Hill on label, not G. F. Hill.

albibasis Mall. (*Trigonometopus*): M44(319–320)	DEI			
albicans Meig. (*Hecamede*): M24(86)				1 Malloch SPHTM
albicens Mall. (*Winthemia*): M68(349)	SPHTM			
albiceps Mall. (*Canace*): M24(87)	SPHTM			
albiceps (Wied.) (*Chrysomyia*): M33(205); M36(327–328); M72(315)				
albiceps Mall. (*Lioscinella*): M134(46)	SPHTM			
albiceps Mall. (*Perrissina*): M119(185–186) ..	USNM	USNM		
albiceps Mall. (*Procissio*): M119(202–203) ..	C'bury M		6 USNM	
albiceps var. *varians* Mall. (*Procissio*): M119(203)..			3 USNM	
albiceps Meig. (*Sarcophaga*): M107(21–22)				
**albiceps* Mall. (*Winthemia*): M68(348); M110(358)	SPHTM			1 Malloch SPHTM; 2 (*W. dispar* Macq.) Malloch BM (NH)
albicincta Mall. (*Veluta*): M119(207–208)			3 USNM	
albicosta Mall. (*Depressa*): M35(401)	CSIRO			
albidipennis Mall. (*Rhamphomyia*): M69(450); M85(425)	USNM			
albifacies Mall. (*Benjaminella*): M25(337) ..	SPHTM	USNM	1 CSIRO	
albifacies Mall. (*Lioscinella*): M134(47)	CSIRO		1 CSIRO	
albifacies Mall. (*Lispa*): M58(154)	BM (NH)			
albifrons Walk. (*Chlorops*): M78(73)				
†*albifrons* Mall. (*Medinella*): M119(236–237) ..	C'bury M		? 1 USNM	
albifrons Mall. (*Prosena*): M85(132)	Probable SPHTM		2 probable SPHTM	
albifrons Mall. (*Spilogona*): M83(382)	C'bury M			
albifrontalis Mall. (*Calliphora*): M34(67) ..	SPHTM		1 USNM	1 Malloch SPHTM
albifrontata Mall. (*Drosophila*): M106(301) ..	BM (NH)			
‡*albimacula* Mall. (*Xenolispa*): M12(610–611) ..	USNM	? USNM	1 lost SPHTM; 1 ? USNM	
albimaculata (Stein) (*Xenolispa*): M12(610) ..				1 Malloch SPHTM; 1 Malloch USNM
albinervis Duda (*Leptocera*): M111(24)				
albipennis Mall. (*Hypaspistomyia*): M18(336); M111(3)	Aust. M (damaged)		1 SPHTM	
albipilus Beck. (*Scoliophthalmus*): M78(67)				
albiseta (Mall.) (*Lasiopleura*): M128(272)				
§*albiseta* Mall. (*Parahippelates*): M18(330) ..	Aust. M			
albisquama Mall. (*Agromyza*): M38(425–426) ..	SPHTM			
albistrigatus de Meij. (*Dacus*): M81(259)				
albitarsis Tonn. & Mall. (*Allophylina*): M39(88)..	Cawthron			
alboapicata Mall. (*Trypanea*): M83(401)	C'bury M	USNM		
alboatra Mall. (*Sapromyza*): M30(41)	SPHTM			
albocincta Mall. (*Rutilia*): M67(108)	CSIRO	CSIRO	1 USNM; 1 CSIRO	
albofasciata (Macq.) (*Leucophenga*): M19(349)				
albohalterata Mall. (*Oscinis*): M116(351)	SPHTM	SPHTM	6 SPHTM; 4 USNM	1 Sabrosky USNM (as *Chlorops*)
albohirta Mall. (*Botanobia*): M134(61–62)				
albolateralis Mall. (*Dacus*): M124(413)	SPHTM	BM (NH)		
albolineata de Meij. (*Euprosopia*): M121(147)				
albopunctatus Macq. (*Chrysopogon*): M43(300)				
albostriata Mall. (*Drosophila*): M19(352–353) ..	Aust. M		1 USNM	
albovirida Mall. (*Rutilia*): M55(307)	Aust. M		1 Aust. M	
albovittata Duda (*Drosophila*): M106(311); M111(20–21)				
albovittata Rond. (*Neohemigaster*): M121(127)				
alcicornis Saunders (*Elaphomyia*): M122(180)				
alcicornis (Saunders) (*Phytalmia*): M122(172–174)				
aliena Mall. (*Erythronychia*): M97(442–443) ..	C'bury M			
aliena Mall. (*Helosciomyza*): M44(324–325) ..	SPHTM	USNM		
¶*aliena* Mall. (*Pygophora*): M10(381–382)	BM (NH)	BM (NH)	5 USNM	1 Malloch USNM
alienata Walk. (*Appygota*): M53(3)				
alienus Mall. (*Pachylophus*): M38(429)	CSIRO			
alpina (Hutt.) (*Huttonella*): M45(362)				
alticeps Mall. (*Euprosopia*): M129(81–82) ..	BM (NH)	BM (NH)	2 BM (NH)	
alticeps Mall. (*Plagiomyia*): M119(171)	Cawthron			1 Malloch USNM
alticeps Mall. (*Scatella*): M25(330)	SPHTM			1 Ferguson SPHTM
alysicarpi Bez. (*Melanagromyza*): M111(19)				
anabilis Ost.-Sack. (*Cleitamia*): M121(109)				
ambusta Mall. (*Homoneura*): M98(34)	? Bruxelles			
ampelophila Loew (*Drosophila*): M106(300–301); M111(21); M112(193)				
amplipennis Skuse (*Plecia*): M46(603)				
amplistrigens Walk. (*Achias*): M121(135)				
analis Macq. (*Australophyra*): M13(667): M31(554)				1 Malloch SPHTM; 5 Malloch USNM
analis Mall. (*Calopygidia*): M68(350–351) ..	CSIRO	CSIRO	2 SPHTM; 1 USNM; 1 CSIRO	
ananassae Dol. (*Drosophila*): M106(301); M112(194)				

* In the original description this was called *W. albicens* in error. The key and other passages and all specimens have *W. albiceps*.

† The USNM specimen labelled paratype by Malloch bears only "934 Coll. Miller". Possibly this is the Queenstown specimen.

‡ Actual specimen of paratype has been lost. It had been renamed *X. bimacula* Beck. by Malloch. Another specimen in SPHTM appears to belong to the type series.

§ The type series comprises 2 ♂♂ and 2 ♀♀ mounted together with no special indication of type or allotype.

¶ Of the five paratypes in USNM, four are as published, "Babinda, N.Q. (Illingworth)". The fifth in "Mer. 14.11.18 (Edmund Jarvis)". This is probably an oversight by Malloch in not citing the different date and collector on this one specimen.

aneura Mall. (*Diplochorda*): M122(175–176) ..	SPHTM			
aneura Mall. (*Megaselia*): M110(338)	BM (NH)			
angulata Hendel (*Pseudepicausta*): M121(119)				
angulata Thomson (*Richardia*): M96(206)				
anguliventris Mall. (*Froggattimyia*): M87(273–274)..	USNM		12 USNM; 2 BM (NH)	
angusticornis Mall. (*Neotachina*): M119(242–243)..	Cawthron		1 USNM	1 Malloch USNM (Dun Mt.)
angustifrons Hendel (*Dasyortalis*): M121(103)				
angustifrons Mall. (*Platytachina*): M119(216) ..	C'bury M		2 USNM	
angustifrons Hendel (*Toxura*): M53(7)				
angustipennis Tonn. & Mall. (*Huttonina*): M48(178)	Cawthron		1 USNM	
angustipennis Mall. (*Paroxyna*): M118(115–116)	Bishop M			
angustipennis Walk. (*Rutilodexia*): M37(352)				
anisonychia Collin (*Hilara*): M83(427)				5 Malloch USNM
annulata Mall. (*Amiota*): M12(612–613)	Aust. M			
annulipes Mall. (*Steganopsis*): M31(548–549) ..	USNM			
annulipes Macq. (*Tapeigaster*): M31(553); M69(436)				7 mentioned in M31 are in USNM
**anomala* (Mall.) (*Lasiopleura*): M128(273)				
anomala Mall. (*Parahippelates*): M24(96); M128(273)	SPHTM	SPHTM	4 SPHTM; 1 USNM	1 ♂ (Mt. Eba) of M128 USNM
anorbitalis Mall. (*Diplotoxa*): M83(416–417) ..	C'bury M			
antarctica Big. (*Helina*): M9(140); M23(42) ..				1 Malloch USNM
antennatis (Hutt.) (*Calliphoroides*): M72(306) ..				1 Malloch USNM
anthracina Mall. (*Homoneura*): M66(208–209) ..	BM (NH)		3 BM (NH)	
anthrax Mall. (*Prochaetops*): M91(5); M112(181)..	Bishop M			
antipodei (Hutt.) (*Xenocalliphora*): M20(639); M72(317)				
anuda Curran (*Homoneura*): M133(143)				
†*aperta* Mall. (*Erythronychia*): M97(447)	Cawthron			1 Malloch USNM
apertum Hutt. (*Calcager*): M55(342); M119(174–175)				2 Malloch USNM
apicalis (Williston) (*Acrosticta*): M73(217); M96(206–207); M103(262)				
apicalis Mall. (*Calliphora*): M36(312)	SPHTM			
apicalis (Stein) (*Dichaetomyia*): M22(326–327) ..				1 Malloch SPHTM; 2 Malloch USNM
apicalis (Williston) (*Euzesta*): M96(206)				
apicalis (Walk.) (*Maorina*): M71(241)				7 Malloch USNM; 2 Malloch C'bury M
apicalis Mall. (*Palpostoma*): M37(339)	SPHTM			
apicalis Mall. (*Pseudepicausta*): M121(119) ..	BM (NH)			
apicalis Sch. (*Pygophora*): M10(382)				2 Malloch SPHTM; 7 Malloch USNM
apicifasciatus Mall. (*Pseudosphenicus*): M126(267–269)	BM (NH)	BM (NH)	2 BM (NH)	
apicinebula Mall. (*Homoneura*): M30(47).. ..	SPHTM		1 USNM	
apicipunctata (Mall.) (*Botanobia*): M38(444); M134(57)				
apicipunctata Mall. (*Gaurax*): M38(444); M134(57)	SPHTM	SPHTM	1 USNM	
apiseriata Mall. (*Homoneura*): M66(210)	Bishop M		1 BM (NH)	
appendiculata Mall. (*Heteria*): M72(326)	C'bury M		1 USNM	6 Malloch USNM
aquaria Hutt. (*Ephydra*): M34(7)				
arabica Mall. (*Hemilea*): M126(271)	BM (NH)		2 BM (NH)	
araucariae (Tryon) (*Diarrhegmoides*): M124(438)				
araucariae Tryon (*Rioxa*): M124(435)				
arcuata Mall. (*Prosena*): M85(129)	SPHTM			
arenaria Tonn. & Mall. (*Sapromyza*): M34(23) ..	C'bury M		1 USNM	
argentata Curran (*Prosena*): M67(114); M85(131, 132)				2 Malloch USNM
argenticeps Mall. (*Lioscinella*): M134(56)	SPHTM			
‡*argentifera* Mall. (*Chaetogaster*): M114(19–20) ..	SPHTM		1 USNM	
argentifera Big. (*Rutilia*): M37(349); M44(333); M55(297–298); M67(107)				1 Engel SPHTM; 3 Malloch USNM
argentifrons Mall. (*Actia*): M68(309–310)	SPHTM			
argentifrons Mall. (*Mycodrosophila*): M35(1) ..	SPHTM		4 USNM	
argentifrons Mall. (*Spilogona*): M83(382–383) ..	USNM	C'bury M		
argyropsila Bez. (*Tapeigaster*): M69(436)				
aristalis Bez. (*Pseudorichardia*): M96(206)				
aristata Mall. (*Maorina*): M71(241)	C'bury M			
armata (Stein) (*Dichaetomyia*): M17(140); M22(323); M27(329–330); M60(405)				1 Malloch SPHTM; 6 Malloch USNM
§*armata* (Mall.) (*Homoneura*): M25(320–321); M44(320)			1 BM (NH)	
armata Mall. (*Lispa*): M22(335–336)	SPHTM			
armata White (*Lonchaegaster*): M45(366) ..				1 Malloch USNM (with ?)
armata Mall. (*Myothyria*): M68(340)	SPHTM			
armata Mall. (*Sapromyzosoma*): M25(320–321) ..	SPHTM		1 USNM	
armatipes Mall. (*Prochaetops*): M91(9–10); M112(183)	Bishop M			
armatipes var. *claripennis* Mall. (*Prochaetops*): M91(10); M112(183)	USNM			
armiceps Mall. (*Palpostoma*): M80(296–297) ..				
armiceps Mall. (*Voriella*): M68(336)	CSIRO			
armipes Beck. (*Lispa*): M12(609); M22(334) ..				1 Malloch SPHTM
¶*armiventris* Mall. (*Prochaetops*): M91(11); M112(184)	Bishop M			

* Allotype and three male paratypes not mentioned in original description in SPHTM. Allotype and one paratype labelled male are apparently females, as is the holotype.

† The determined specimen in USNM is labelled a paratype but was not cited in the original description.

‡ The paratype in USNM is from Gisborne, Victoria; this detail was omitted by Malloch, M114(20).

§ The paratype listed for BM (NH) must have been designated subsequent to publication of this species and so should not be considered a true paratype.

¶ Three of the specimens recorded in M112(184) are in USNM labelled paratypes but they cannot be true paratypes.

artemisiae Kaltenbach (*Agromyza*): M12(622) ..				1 Malloch SPHTM
aspiciens (Walk.) (*Achiosoma*): M121(130–131)				
assimilis Mall. (*Calliphora*): M36(317–318)				
**assimilis* Tonn. & Mall. (*Ephydra*): M34(7–8) ..				
assimilis Wied. (*Lispa*): M22(337–338); M58(153)				2 Malloch USNM
assymilis (Macq.) (*Paramphibolia*): M55(313) ..				1 Malloch Aust. M
astrolabei Bd. (*Cleitamia*): M121(109)				2 Malloch SPHTM; 1 Malloch Aust. M; 2 Malloch USNM
asymmetrica Mall. (*Homoneura*): M35(15).. ..	SPHTM			
†*atra* Mall. (*Borboroides*): M24(85–86)	SPHTM			
atra Mall. (*Dacus*): M118(113)	Bishop M		1 USNM	
atra Mall. (*Gynatoma*): M83(426)				
atra Mall. (*Neoscatella*): M111(9–10); M112(200)..	Bishop M		37 Bishop M; 22 USNM; 1 BM (NH)	
‡*atra* Mall. (*Neotryphera*): M119(218–219) ..	C'bury M			1 Malloch USNM
atra Meig. (*Phytomyza*): M110(341)				
atra Meig. (*Pseudonapomyza*): M110(341)				
atrata Mall. (*Depressa*): M30(31–32); M38(401) ..	SPHTM			Tasmanian spec. (M38) USNM
atrata Mall. (*Podanema*): M43(308); M46(611) ..	USNM			
atrata (Mall.) (*Toxopoda*): M46(611)				
atratipes Mall. (*Lispocephala*): M52(83)	Bishop M			
atratula Mall. (*Anthracomyza*): M36(319) ..	CSIRO			1 Malloch Aust. M
atratula Mall. (*Cylindromyia*): M68(314)	SPHTM	USNM	1 CSIRO (damaged)	
atratula Mall. (*Dohrniphora*): M25(334)	SPHTM			
atratus Mall. (*Occisor*): M119(206, 207)	Cawthron			
atribasis (Walk.) (*Formosia*): M37(350–351); M55(311); M67(105)				13 Malloch USNM; 2 Engel SPHTM; 1 Malloch Aust. M
atriceps Mall. (*Asteia*): M93(115–116); M112(190)	Bishop M			
atricornis Mall. (*Batrachomyia*): M25(336); M128(265)	SPHTM		1 SPHTM; 2 USNM	1 Malloch SPHTM; 3 Malloch Sabrosky Coll.
atricornis (Mall.) (*Cadrema*): M128(277)				
atricornis Mall. (*Deltasoma*): M78(66–67); M128(275)	SPHTM			
atricornis Mall. (*Fergusonina*): M24(92); M86(214)	CSIRO			
atricornis Mall. (*Hippelates*): M38(438–439) ..	USNM			
atricornis Meig. (*Phytomyza*): M12(622)				2 Malloch, 1 Hering SPHTM
atricornis Mall. (*Platytachina*): M119(212–213) ..	USNM			
atricornis Mall. (*Prochaetops*): M112(181–183) ..	Bishop M	Bishop M		
§*atridorsata* Mall. (*Megaselia*): M110(337) ..	Bishop M			
atrifacies Mall. (*Discocerina*): M106(318–319) ..	BM (NH)			
atrifacies Mall. (*Homoneura*): M133(139–140) ..	BM (NH)			
atrifemur Mall. (*Pollenia*): M72(321)	C'bury M			
atrifrons Mall. (*Czernyola*): M135(209)	Bishop M		2 USNM	
atrifrontata Mall. (*Xenolispa*): M8(280); M10(384); M12(610).	BM (NH)			
atrimana Mall. (*Paralauxania*): M38(410) ..	SPHTM		2 USNM; 3 CSIRO	
atrimana Mall. (*Paralimna*): M25(326)	SPHTM		1 USNM	1 Ferguson SPHTM
atrimana Mall. (*Sapromyza*): M45(359–360)				
atripennis Mall. (*Neomedina*): M110(362–364) ..	Bishop M		1 BM (NH)	
¶*atripennis* Mall. (*Trypanocentra*): M124(428, 430)				
atripes Mall. (*Exechopalpus*): M67(131)	SPHTM			
atripes Mall. (*Heteria*): M72(331)	USNM			
atripes Mall. (*Lasiocalypter*): M67(121–122) ..	SPHTM			
atriseta (Mall.) (*Cadrema*): M128(277)				
atriseta Mall. (*Gaurax*): M19(355); M38(438) ..	SPHTM			
atriseta (Mall.) (*Hippelates*): M38(438); M128(277)				
atrithorax Mall. (*Limnophora*): M58(187)	Bishop M		1 BM (NH)	
atriventris Mall. (*Cadrema*): M128(278–279) ..	SPHTM			
atriventris Mall. (*Sapromyza*): M24(83–84) ..	USNM	USNM	2 USNM	
atroapicata Mall. (*Thyridula*): M19(358); M38(441); M128(275)	SPHTM			1 Malloch SPHTM; 2 Malloch Sabrosky Coll.
atrogrisea Mall. (*Homoneura*): M30(46–47); M38(419); M59(65)				
atropivora R.-D. (*Sturmia*): M110(355)				
atropunctipes Mall. (*Metopomyia*): M8(272–273); M12(603)	BM (NH)			2 Malloch SPHTM; 1 Malloch USNM
attenuata Mall. (*Pseudepicausta*): M82(27–28); M121(117)	DEI		1 USNM	
attenuata (Mall.) (*Scotinosoma*): M121(117)				
augur (Fabr.) (*Calliphora*): M36(310); M46(613); M107(20)				4 Malloch, 3 Taylor SPHTM; 3 Malloch USNM
aurantiaca (Stein) (*Heliographa*): M29(508); M60(399)				2 Malloch USNM (with ?)
aurea Macq. (*Lonchaea*): M43(306); M74(241)				
aurea Town. (*Protomeigenia*): M55(323)				
aureifacies Mall. (*Spilogona*): M83(383)	C'bury M			

* The name *assimilis* is used for the species described as *E. similis* in a key on the same page but above the description.

† Type specimen is labelled *B. australis*. Its head has been lost.

‡ The determined specimen in USNM is wrongly labelled a paratype.

§ The label on the type is Samoa, Savaii, Salailua, E. J. Bryan, Jr., 23-V-24. This is not in agreement with the published locality.

¶ This is a new name proposed by Malloch for *T. nigripennis* Hendel.

aureiventris (Curran) (*Hyalomyia*): M67(96)				
aureocapitata Mall. (*Sapromyza*): M30(44) ..	SPHTM			
aureocauda Curran (*Palia*): M55(335)				
aureonotata (Macq.) (*Calliphora*): M20(640); M36(303); M72(316)				3 Malloch USNM
aureopyga Curran (*Zitta*): M55(335)				
aureovitta Mall. (*Euprosopia*): M121(151–152) ..	BM (NH)		1 BM (NH)	
auriceps Mall. (*Paurothrix*): M73(236)	Hamburg			
auriventris Mall. (*Calliphora*): M36(315–316); M84(65)				
auronotata (Macq.) (*Ptilonesia*): M20(640); M36(303); M72(316)				
austeni Hendel (*Angituloides*): M129(90–91)				
austeni Sharp (*Lamprogaster*): M121(143); M129(76)				1 Malloch USNM; 1 Malloch SPHTM; 1 Malloch Aust. M
australasiae Mall. (*Helina*): M13(669–670); M23(41)	BM (NH)			1 F. M. Snyder, 2 Malloch USNM
australasiae Mall. (*Hyalomyodes*): M68(325) ..	SPHTM			
australiae Mall. (*Heteromeringia*): M30(48); M69(435)	SPHTM			1 Malloch USNM
australiae Mall. (*Scatella*): M25(331)	SPHTM			
**australica* Mall. (*Calliphora*): M36(314)				4 Malloch SPHTM; 2 Malloch USNM
australiensis Mall. (*Delta*): M68(332–333).. ..	SPHTM		1 USNM; 1 SPHTM; 2 CSIRO	
australiensis (Sch.) (*Erythronychia*): M97(445–446)				3 Malloch USNM
australina Hendel (*Acanthoneura*): M124(432)				
australis Mall. (*Achias*): M121(137–138)	SPHTM		2+2 damaged USNM	
australis Bd. (*Calliphora*): M84(66)				
australis Mall. (*Cerodonta*): M24(89–90)	SPHTM		1 SPHTM	1 Ferguson SPHTM
australis Mall. (*Dasycoelopa*): M101(349–350) ..	USNM	Very damaged SPHTM		
australis (Mall.) (*Doddiana*): M68(341); M100(135–136)				
†*australis* var. *maculiventris* Mall. (*Doddiana*): M100(136)	SPHTM		1 BM (NH); 1 SPHTM; 1 USNM	
australis Mall. (*Ephydroscinis*): M18(331–332) ..	SPHTM	USNM		
australis Mall. (*Fannia*): M12(605–606)	Aust. M		6 USNM	
australis Beck. (*Formosina*): M116(355)				
‡*australis* Mall. (*Haematobia*): M89(506)	USNM	USNM	2 USNM	
australis Mall. (*Hydrotaea*): M13(667)	BM (NH)	BM (NH)	3 SPHTM; 3 USNM; 3 BM (NH)	
australis Mall. (*Liodrosophila*): M45(354–355)				
australis Mall. (*Lipara*): M128(279–280)	SPHTM			
australis Mall. (*Lispocephala*): M12(604–605) ..	BM (NH)			
australis (Hutt.) (*Macrocanace*): M34(5–6)				
australis Mall. (*Madiza*): M128(276)	CSIRO			
australis Hutt. (*Ochthiphila*): M34(5–6)				
australis Mall. (*Pachyneres*): M16(205); M46(606); M51(138–140)	Aust. M			1 Malloch USNM
australis Mall. (*Pygophora*): M10(383)	BM (NH)			
australis B. & B. (*Rhinomyiobia*): M67(129–130)..				2 Malloch USNM; 1 Malloch SPHTM
§*australis* Mall. (*Rhyncomydaea*): M12(604); M9(135)	BM (NH)		3 BM (NH)	2 Malloch SPHTM; 5 Malloch USNM
australis J. & T. (*Sarcophaga*): M110(365) ..				1 Parker SPHTM
australis Mall. (*Scaptomyza*): M12(618–619) ..	USNM			3 Malloch SPHTM; 7 Malloch USNM
australis Mall. (*Semisuturia*): M37(340–341) ..	SPHTM			
australis Mall. (*Stenomicra*): M40(25)	BM (NH)		4 USNM	
australis Mall. (*Tephrella*): M124(456) ..	SPHTM			
australis Mall. (*Trypaneoides*): M44(321–322) ..	SPHTM			
avicola Mall. (*Sapromyza*): M38(416–417) ..	CSIRO			
badia (Hutt.) (*Oscinosoma*): M83(412–413) ..				10 Malloch Sabrosky Coll.
bakeri Mall. (*Plecia*): M46(605)	USNM	USNM	3 USNM	
bakeri Mall. (*Pseudosophira*): M124(415)	USNM		1 SPHTM	
baldwini Mall. (*Actia*): M68(306)	SPTHM			
balteata Bergroth (*Drosophila*): M12(618)				
bancrofti Mall. (*Antipodomyia*): M4(429–430); M23(44)	BM (NH)	BM (NH)	2 BM (NH)	
bancrofti (Mall.) (*Cadrema*): M128(277)				
bancrofti Mall. (*Hippelates*): M24(97)	SPHTM			
barbata Hendel (*Dasyortalis*): M121(103)				
barbifera Hendel (*Pogonortalis*): M46(612) ..				1 Malloch USNM
barnardi (Bergroth) (*Homoneura*): M35(15) ..				1 Malloch SPHTM; 3 Malloch USNM

* The two specimens listed from USNM were found in the Malloch collection under a pencilled label " australica ". One from Kosciusko, 7 December, 1922, agrees with data for the holotype; the other, Blackheath, 24 December, 1921, agrees with a male paratype. Since type material cannot be found elsewhere, they may be type and paratype, and have been labelled accordingly " possible holotype " and " possible paratype ".

† The type (28.ix.1922) is in SPHTM as also is a Kenthurst specimen (labelled paratype). One specimen (National Park 29.ix.1922) labelled paratype, is in USNM.

‡ The type ♂ and the paratype ♂, on the pin with Malloch's label " Type " are actually from Stapleton, N.T., G. F. Hill.

§ One specimen in SPHTM determined by Malloch is incorrectly labelled, and appears to be *R. pollinosa* Mall.

basalis Ender. (*Brea*): M121(125)				
basalis Mall. (*Hyalomyia*): M67(96)	SPHTM			
basalis Walk. (*Lamprogaster*): M121(144)				
basalis Curran (*Paliana*): M55(335); M68(344–345)				
basilaris Wied. (*Rivellia*): M73(221)				
basiseta Mall. (*Megaselia*): M110(336–337) ..	Bishop M		1 BM (NH)	
beckeri Mall. (*Conioscinella*): M128(285–286) ..	SPHTM	SPHTM	14+8 presumed SPHTM; 11 USNM; 4 CSIRO	
beckeri var. *grisella* Mall. (*Conioscinella*): M128(286)	SPHTM			
beirne Brues (*Plastophora*): M2(501)				
bella Curran (*Prosena*): M67(115–116); M85(131)				
bellula Bergroth (*Drosophila*): M12(613–614)				
benefica Mall. (*Pseudoleucopis*): M70(490); M130(266)	CSIRO		2 USNM; 1 CSIRO	
bezzii Miyake (*Dacus*): M81(265)				
**biannulata* Mall. (*Lioscinella*): M134(48)				
biarcuata (Walk.) (*Cleitamia*): M121(110)				
biarcuatus Walk. (*Dacus*): M124(464)				
biarmata Mall. (*Euprosopia*): M57(512); M69(431); M82(8)	DEI			
biarmata Mall. (*Phytalmia*): M122(174)	BM (NH)		6 BM (NH)	
biarmata Mall. (*Senostoma*): M114(14–15)	SPHTM			5 D. J. Clark BM (NH)
bicolor Macq. (*Lamprogaster*): M45(349)				3 Malloch USNM
bicolor (Macq.) (*Linnaemyia*): M55(317)				1 Malloch Aust. M
bicolor Mall. (*Paracoenosia*): M119(256)	USNM			
bicolor Mall. (*Prochaetops*): M91(5–6); M112(182)	Bishop M			
bicolor (Macq.) (*Rioxa*): M124(436)				1 Bezzi SPHTM
bicolor Mall. (*Scaptomyza*): M106(297–298) ..	BM (NH)			
bicoloripes Mall. (*Oscinosoma*); M111(30) ..	Bishop M	Bishop M	8 Bishop M; 6 USNM	
†*bicoloripes* Mall. (*Sapromyza*): M30(38)	SPHTM	SPHTM		
bicornis Mall. (*Cadrema*): M111(28–29)	Bishop M	Bishop M	30 Bishop M; 14 USNM	
bidentata Mall. (*Atherigona*): M44(326–327)				
bifasciata (Stein) (*Dichaetomyia*): M6(420)				
bifida Mall. (*Phaoniella*): M119(217)	Cawthron		5 USNM	
bifidus Bez. (*Pseudospheniscus*): M124(450); M127(241)				
bilimbata Bez. (*Drosophila*): M106(311)				
bilineata de Meij. (*Euprosopia*): M121(149–150) ..				1 Malloch SPHTM
bilineata (Hutt.) (*Poecilohetaerella*): M34(26) ..				3 Malloch; 1 Tonnoir USNM
bilineatus Fabr. (*Anabarrhynchus*): M90(242)				
‡*bilineatus* Mall. (*Chilocryptus*): M111(26–27); M112(188)	Bishop M			2 Malloch USNM
bimacula Mall. (*Maorina*): M71(237–238) ..	C'bury M		4 USNM	1 Malloch USNM
bimacula Beck. (*Xenolispa*): M12(610)				1 Malloch SPHTM
bimaculata Mall. (*Upolumyia*): M106(283) ..	Bishop M	BM (NH)		
bimaculata Mall. (*Xanthotrypeta*): M124(444); M126(250–251)	BM (NH)		1 BM (NH)	
§*bimaculatus* Hendel (*Scholastes*): M73(223); M121(129); M129(73)				1 Malloch SPHTM; 1 Malloch Aust. M
binigra Mall. (*Zealandotachina*): M119(233–234) ..	USNM			
binotatus (Thoms.) (*Trigonometopsis*): M24(82–83); M38(412); M59(37)				1 Malloch SPHTM; 1 Malloch USNM
bioculata (de Meij.) (*Homoneura*): M61(413)				
bipartita Mall. (*Chloropella*): M24(94–95)	SPHTM			
bipuncta Mall. (*Lispocephala*): M60(394)	Amsterdam			
bipunctata Mall. (*Aneuria*): M72(341)	C'bury M	Presumed USNM		9 Malloch USNM
bipunctata Hendel (*Euxestomoea*): M121(106)				
bipunctata (Hutt.) (*Maorimyia*): M48(155–156); M103(325–327)				1 Malloch USNM
biroi de Meij. (*Antineura*): M121(104)				
biroi Hendel (*Laglaisia*): M121(112)				
bischofi Kertesz (*Ptilona*): M124(464)				
biserialis (Macq.) (*Austrophorocera*): M68(344) ..				1 Malloch USNM
biseriata Mall. (*Clusiosoma*): M124(426)	SPHTM		4 USNM (damaged); 1 DEI	
biseriata Mall. (*Dicladochaeta*): M96(218); M112(195)	Bishop M	Bishop M	2 Bishop M; 3 USNM	2 Malloch Bishop M
biseriata Mall. (*Incurviseta*): M38(406)	CSIRO	CSIRO	2 USNM	
biseriatus Mall. (*Chaetophthalmus*): M68(311) ..	USNM			
biseta Mall. (*Adrama*): M123(332–333)	SPHTM			
biseta Mall. (*Fergusonina*): M86(215)	SPHTM			1 Malloch USNM (with ?)
biseta Mall. (*Scaptomyza*): M96(222); M112(194) ..	Bishop M			
bisetosa Bez. (*Paurothrix*): M73(235)				
bisetosa Mall. (*Prosena*): M85(130)	SPHTM	USNM		1 Malloch SPHTM (headless)
bispina Mall. (*Lispocephala*): M52(75)	Bishop M			
bispinosa (Beck.) (*Oscinelloides*): M128(268) ..				1 Malloch SPHTM
bistriga Walk. (*Sophira*): M124(464)				

* This is a new name for *Oscinosoma nigroannulata*, M78(61).

† Type and allotype mounted on the same card, not type and paratype as mentioned in the description.

‡ The two identified specimens in USNM were labelled paratypes by Malloch but are the specimens recorded in M112(188).

§ Specimen in Aust. M was originally labelled *S. bipunctatus* Hendel.

bistrigata Hendel (*Scotinosoma*): M121(117) ..				2 Malloch USNM
bivittata Mall. (*Atherigona*): M60(397)	Amsterdam			
bivittata Mall. (*Enicopterina*): M127(241)	BM (NH)			1 F. van Emden BM (NH)
bivittata Mall. (*Limnohelina*): M72(298)	USNM		1 USNM	
bivittata Stein (*Lispa*): M60(391)				
bivittata Mall. (*Prochaetops*): M91(6–7); M112(182)	Bishop M			1 Malloch USNM (labelled paratype)
bivittigera Mall. (*Lioscinella*): M134(55–56) ..	SPHTM			
blundelli Mall. (*Oscinis*): M116(341–342)	CSIRO		1 CSIRO	
botanica Mall. (*Oscinis*): M116(348)	SPHTM			
brachycerus Knab & Mall. (*Microdon*): M1(235–236)	USNM			
brachyophthalmus Walk. (*Achias*): M121(135–136)..				1 Malloch, 1 Aldrich SPHTM; 12 Malloch USNM
brevicornis Hendel (*Campylocera*): M53(17)				
brevicornis (Saunders) (*Diplochorda*): M122(178)				
brevicornis Mall. (*Sapromyza*): M35(10)	SPHTM		2 USNM	
brevigaster (Macq.) (*Chaetophthalmus*): M55(319) ..				15 Malloch USNM; 15 Malloch SPHTM
brevipalpus Mall. (*Avibrissina*): M97(438–439); M119(179)	Cawthron		4 USNM	
brevis Mall. (*Actia*): M68(309)	SPHTM			
brevis Mall. (*Huttonina*): M72(343)	USNM			
breviseta Mall. (*Ephydra*): M25(329)	SPHTM		3 USNM	
breviseta Mall. (*Eustacomyia*): M37(337–338); M67(133)	SPHTM			
breviseta Mall. (*Siphunculina*): M19(358–359) ..	SPHTM		2 SPHTM; 6 USNM	1 Malloch SPHTM
brevispina Mall. (*Lispocephala*): M52(81)	Bishop M			
brevivitta Walk. (*Trypeta*): M124(464)				
bronneci Mall. (*Apulvillus*): M112(198–199) ..	Bishop M		2 USNM; 4 Bishop M	
brouni (Hutt.) (*Cerosomyia*): M119(198)				
brunnea Mall. (*Cylindromyia*): M68(315)	CSIRO			
brunneicosta (Mall.) (*Lasiopleura*): M12(620–621); M128(272)				
brunneicosta Mall. (*Limnophora*): M65(332) ..	BM (NH)			
brunneicosta Mall. (*Parahippelates*): M12(620–621)	S.A. Mus			
brunneifrons Mall. (*Tapeigaster*): M35(16) ..	USNM			
brunneifrons Mall. (*Thyridula*): M38(442); M128(275)	SPHTM			
brunneipennis Mall. (*Dichaetomyia*): M60(406) ..	Amsterdam			
brunneipennis Mall. (*Drosophila*): M12(617–618)..	Aust. M			1 Malloch USNM
brunneoapicata Mall. (*Botanobia*): M134(59) ..	SPHTM			
brunneovittata Mall. (*Sapromyza*): M30(45–46); M35(12)	SPHTM			1 Malloch SPHTM; 1 Tonnoir, 3 Malloch USNM
brunniceps Mall. (*Perrissina*): M119(186–187) ..	Cawthron			
bryani Mall. (*Drosophila*): M106(310)	Bishop M		1 BM (NH)	2 Harrison USNM
bryani Mall. (*Oscinosoma*): M74(248) ..	Bishop M			1 Malloch BM (NH)
bryani Mall. (*Xenognathus*): M73(226)	Bishop M			1 Malloch BM (NH)
bryoniae Tryon (*Dacus*): M124(411)				
bullans (Wied.) (*Camaromyia*): M103(274); M124(460–461)				1 Malloch SPHTM; 10 Malloch and Bezzi USNM
bullans Wied. (*Trypeta*): M124(460)				
buloloae Mall. (*Pseudina*): M124(446–447) ..	SPHTM			
burnsi Mall. (*Austrometopia*): M69(438)	SPHTM		1 USNM; 2 SPHTM	
buruensis Mall. (*Dichaetomyia*): M60(402) ..	Amsterdam			
buruensis Mall. (*Steganopsis*): M61(409–410) ..	Amsterdam			
buscki Coq. (*Drosophila*): M12(616–617)				1 Malloch SPHTM; 3 Malloch USNM
buxtoni Mall. (*Mycodrosophila*): M106(286–287) ..	BM (NH)			
buxtoni Mall. (*Pygophora*): M58(160)	Bishop M		2 BM (NH); 1 USNM	
caerulea (Macq.) (*Celetor*): M57(506)				3 Malloch USNM
caeruleifrons (Macq.) (*Orthellia*): M107(8–9)				
caeruleiventris Big. (*Maria*): M121(124)				
caerulescens (Stein) (*Helina*): M9(137); M23(41)..				1 Malloch SPHTM; 15 Malloch USNM
caesar (Linné) (*Lucilia*): M20(639); M36(322)				
cairnsi Mall. (*Lioscinella*): M134(49) ..	SPHTM			
calcitrans (Linné) (*Stomoxys*): M58(175); M89(402–403)				1 Austen, 1 Marshall SPHTM
calliphorosoma Mall. (*Macrochloria*): M55(326); M114(20)	Aust. M		3 Aust. M	1 Malloch SPHTM; 3 Malloch USNM
calliphorosoma var. *rufipes* Mall. (*Macrochloria*): M114(20)	SPHTM	SPHTM	2 SPHTM; 2 USNM	
callipygus Gerst. (*Formosia*): M55(309)				
caloptera Big. (*Laglaisia*): M121(112)				
calyptrata Mall. (*Helina*): M17(142–143); M23(41)	SPHTM	USNM		
campbelli (Mill.) (*Hyalomyia*): M72(308)				
cana Walk. (*Lispa*): M12(607–608); M22(333); M58(155); M60(392)				2 Malloch SPHTM; 6 Malloch USNM
cana Hutt. (*Procissio*): M119(204)				1 Malloch USNM
cana var. *valida* Hutt. (*Procissio*): M119(204)				
canaliculata Beck. (*Chlorops*): M78(71)				
canaliculata Beck. (*Oscinis*): M116(345)				
canaliculata var. *trisulcata* Mall. (*Oscinis*): M116(345)				
canicularis (Linné) (*Fannia*): M12(605); M72(305)				3 Malloch SPHTM

caniventris Bez. (*Trypaneoides*): M66(203) ..				5 Malloch USNM
capitata (Wied.) (*Ceratitis*): M124(451)				
carbonaria Hutt. (*Lauxania*): M34(26); M71(231)				
carbonarius Hendel (*Dacus*): M118(113)				
carinata (Stein) (*Rhyncomydaea* or *Hardyia*): M12(604); M31(554)				1 Malloch Aust. M; 5 Malloch USNM
carinata Mall. (*Tricimba*): M19(356–357); M38(444); M83(409)	SPHTM			
carinifacies Mall. (*Tricimba*): M38(443)	CSIRO		1 USNM	
casei (Linné) (*Piophila*): M25(316); M96(215); M103(246)				1 Malloch SPHTM
cassiniae Mall. (*Tephritis*): M83(395–396).. ..	C'bury M		1 USNM	4 F. A. Perkins BM (NH)
castanea (Hutt.) (*Neolimnia*): M48(165)				
castaneus Hutt. (*Anabarrhynchus*): M90(241)				
castigata Mall. (*Helina*): M23(41, 44)	SPHTM		2 USNM	
catharinae de Meij. (*Cleitamia*): M121(107)				
caudatus Fabr. (*Dacus*): M81(256)				
cavifrons Mall. (*Cairnsimyia*): M80(294–295) ..	DEI		1 USNM	
celyphoides (Walk.) (*Mesoctenia*): M121(123)				
centralis Mall. (*Adrama*): M126(247–249) ..	BM (NH)	BM (NH)	1 BM (NH)	1 F. van Emden BM (NH)
centralis Mall. (*Calliphora*): M36(311); M46(613)..	SPHTM			2 Malloch, 5 Taylor SPHTM; 4 G. H. Hardy BM (NH)
centralis Mall. (*Clusiosoma*): M124(426)	SPHTM		2 USNM (1 fragmentary)	
centralis Mall. (*Dichaetomyia*): M60(404) ..	Amsterdam			
centralis Mall. (*Plethochaetigera*): M119(195–196)				
centralis Mall. (*Thyridula*): M24(96); M38(441); M128(274–275)	SPHTM		1 ? CSIRO	1 Malloch Sabrosky Coll.
centralis Mall. (*Trypanea*): M83(402)	C'bury M		1 USNM	
ceres Curran (*Steganopsis*): M138(133)				
certima Curran (*Demoticus*): M47(653)				6 Malloch USNM
cervicornis Gerst. (*Phytalmia*): M122(171–172) ..				1 Malloch SPHTM; 1 Malloch Aust. M
chalcogaster Wied. (*Ophyra*): M13(666); M58(170); M65(333); M95(196)				2 Malloch SPHTM; 1 Malloch USNM
chalcura Bez. (*Sarcophaga*): M62(269)				
chalybea (Dol.) (*Pseudepicausta*): M121(118); M129(72)				2 Malloch SPHTM; 1 Malloch USNM
chathamensis Mall. (*Allophylopsis*): M39(94–95)	C'bury M			
cheesmanae Mall. (*Chaetoscatella*): M112(199–200)	BM (NH)		9 BM (NH)	3 Malloch USNM
cheesmanae Mall. (*Cleitamia*): M121(110–111) ..	BM (NH)			
cheesmanae Mall. (*Homoneura*): M132(21–22) ..	BM (NH)			
cheesmanae Mall. (*Limnophora*): M65(331) ..	BM (NH)		5 BM (NH)	
chinensis (Fabr.) (*Ommatius*): M56(408)				1 Malloch USNM
chorceides Bez. (*Lonchaea*): M43(306)				
**chrysame* (Walk.) (*Amenia*): M67(101); M99(75–76)				2 Paramonov SPHTM; 2 Malloch USNM
chryseps Mall. (*Sturmia*): M110(356–357) ..	BM (NH)	BM (NH)	1 BM (NH)	
chrysis Mall. (*Hyalomyia*): M67(95)	SPHTM			
chrysothrix Bez. (*Dexopollenia*): M36(324)				
chrysotoxus Hendel (*Dacus*): M81(256)				
ciliata Hendel (*Desmometopa*): M18(336); M106(327)				
†*ciliata* Mall. (*Lispocephala*): M60(393)	Amsterdam			1 Malloch USNM
cilierura (Rond.) (*Hylemyia*): M17(139); M72(291)				1 Malloch SPHTM
‡*cilifera* Mall. (*Apilia*): M68(345–346)	CSIRO		1 ? USNM	
cilipes Macq. (*Masicera*): M110(358)				
cincta Towns. (*Protomiltogramma*): M36(335); M69(445)				1 Malloch SPHTM; 1 Malloch USNM
cinctus (Guér.) (*Scholastes*): M73(222); M98(36); M121(128); M129(73)				4 Malloch SPHTM
cinerea Mall. (*Apalpostoma*): M67(134–135) ..	SPHTM			
cinerea Mall. (*Chaetometopia*): M69(443–444) ..	CSIRO			
cingulata Mall. (*Formosia*): M67(105)	CSIRO			
cingulata (Macq.) (*Zosteromyia*): M67(111) ..				2 Malloch SPHTM; 2 Malloch USNM
cingulatus (Fabr.) (*Eristalis*): M7(227)				
cingulatus (Fabr.) (*Helophilus*): M7(227)				
cingulatus (Fabr.) (*Mallota*): M7(227)				
cingulatus (Fabr.) (*Pilinasica*): M7(227)				
cingulatus Fabr. (*Syrphus*): M7(227)				
circumsetosa de Meij. (*Apiochaeta*): M110(334)				
cirrhura Bez. (*Sarcophaga*): M75(481)				
citricola Bez. (*Lonchaea*): M43(307)				
claripennis Mall. (*Dichaetomyia*): M60(407) ..	Amsterdam			
claripennis Mall. (*Fenwickia*): M72(337)	C'bury M		2 C'bury M; 4 USNM	1 F. van Emden BM (NH)
claripennis Mall. (*Limnophora*): M65(332) ..	BM (NH)		8 BM (NH)	
claripennis Mall. (*Macquartia*): M97(435–436); M119(221–222)	C'bury M			
claripennis Mall. (*Prochaetops*): M91(10)	Bishop M			
clarki Mall. (*Calliphora*): M36(316)				
clarki (Hutt.) (*Neotachina*): M119(243–244)				
clarkii Hutt. (*Tachina*): M97(434); M119(243–244)				
clathrata Nowicki (*Cerosomyia*): M119(197)				
cleitamina Edw. (*Ortaloptera*): M124(454)				
clelandi Ferg. (*Spaniopsis*): M79(274)				4 Malloch USNM

* See also *Amenia parva*.

† The specimen in USNM has the same data as given for one of the paratypes and may possibly have been intended as such.

‡ The ♂ from Cairns District, noted in the original publication, is labelled "paratype?" by Malloch.

coalescens (Hendel) (*Hesoctenia*): M121(123) ..				1 Malloch USNM
cockaynei (Mill.) (*Hyalomyia*): M72(309)				
coeruleothorax Linder (*Chrysopilus*): M79(276)				
comma Mall. (*Semosia*): M106(273–275)	BM (NH)		2 BM (NH)	
communis Mall. (*Austrodexia*): M67(125) ..	CSIRO		2 USNM	1 Curran SPHTM; 1 Malloch BM (NH)
communis Mall. (*Botanobia*): M134(62–63) ..	SPHTM	SPHTM	1 USNM; 8 SPHTM	
communis Mall. (*Discocerina*): M106(319–320) ..	Bishop M		8 BM (NH)	
compitalis Collin (*Atrichopleura*): M83(424) ..				5 Malloch USNM
complens (Walk.) (*Dasyortalis*): M57(506); M121(102)				1 Malloch SPHTM
complens var. *fasciata* (Curran) (*Dasyortalis*): M121(103); M129(68)				1 Malloch SPHTM
complens var. *separata* Mall. (*Dasyortalis*): M121(103)	BM (NH)			
completa Mall. (*Pseudepicausta*): M82(27); M121(117)	DEI		2 USNM	
completa (Mall.) (*Scotinosoma*): M121(117)				
completa Mall. (*Trypanea*): M83(400–401).. ..	C'bury M			
compressa Town. (*Sumpigaster* or *Mesembriomintho*): M55(315); M67(110)				1 Curran SPHTM
concisa (Walk.) (*Diplochorda*): M122(177–178) ..				1 Malloch Aust. M
confinis Walk. (*Calobata*): M110(346)				
confluens Mall. (*Botanobia*): M134(63–64) ..	SPHTM			
confluens Mall. (*Lispocephala*): M52(79)	Bishop M			
conformis (Skuse) (*Xenoplatyura*): M46(601–602)				
**confusa* Mall. (*Formosia*): M55(309–310) ..	Aust. M		9 Aust. M	2 Paramonov, 5 D. J. Clark BM (NH); 1 Malloch USNM
confusa Mall. (*Plecia*): M46(605)	BM (NH)	BM (NH)		
confusa Mall. (*Trypaneoides*): M133(145)	BM (NH)			
confusa Mall. (*Xarnuta*): M124(440); M126(261)..	BM (NH)			
conjuncta Mall. (*Atrichopleura*): M83(424–425)				
conjuncta Mall. (*Dichaetophora*): M44(324) ..	USNM			
conjuncta Hend. (*Euprosopia*): M45(345); M57(512); M69(429); M82(8)				1 Malloch USNM; 1 Malloch SPHTM
†*conjuncta* Mall. (*Leucophenga*): M19(350) ..	Aust. M		1 USNM	
connata (Thoms.) (*Rivellia*): M45(351); M63(100); M70(491); M73(221); M121(120)				1 Malloch SPHTM
connexa Mall. (*Euprosopia*): M129(79)	BM (NH)		3 BM (NH)	1 Malloch Aust. M
connexa Hend. (*Rivellia*): M121(121)				1 Malloch SPHTM; 1 Malloch Aust. M
conopsea Duda (*Lasiopleura*): M114(23–24); M128(273)				1 Malloch SPHTM; 2 Malloch Sabrosky Coll.
conspicua Mall. (*Arrhenomyza*): M55(322) ..	CSIRO			2 Malloch USNM
conspicua Mall. (*Sapromyza*): M61(414)	Amsterdam			
contacta Walk. (*Piophila*): M25(316); M35(8); M74(251)				
contraria Walk. (*Brea*): M121(124)				1 Malloch SPHTM; 25 Malloch USNM
convergens Mall. (*Gitonides*): M35(7)	SPHTM			
convergens Mall. (*Hopkinsomyia*): M106(289–291)	BM (NH)	Bishop M	2 BM (NH)	
‡*convergens* Mall. (*Oscinis*): M116 (340–341) ..			1 ? USNM	
convexa Mall. (*Drosophila*): M106(303–304) ..	BM (NH)		1 BM (NH)	
convexa Mall. (*Tricimba*): M38(444)	CSIRO		2 USNM; 2 CSIRO	
coprophila de Meij. (*Sepsis*): M25(313)				1 Malloch SPHTM
cornuta Hend. (*Monocera*): M133(135)				
corona Curran (*Rutilia*): M78(78)				
costalis Mall. (*Achiasoma*): M121(130–131) ..	BM (NH)			
costalis Mall. (*Hyalomyia*): M55(284); M67(95) ..	CSIRO			
costalis Walk. (*Lamprogaster*): M121(141)				
costalis Walk. (*Stilbomyia*): M67(102)				1 Malloch USNM
costata Meig. (*Orchisia*): M58(157)				
costomaculata (Mall.) (*Lasiopleura*): M128(270)				
costomaculata Mall. (*Parahippelates*): M18(329–330); M128(270)	Aust. M		1 SPHTM	
cothurnata Panzer (*Calobata*): M110(345)				
cothurnata (Big.) (*Pseudodiopsis*): M117(438) ..				1 Malloch Aust. M
crassa Mall. (*Lioscinella*): M134(49)	SPHTM			
crassifemur Mall. (*Lispocephala*): M52(87) ..	Bishop M			
crassifemur Mall. (*Merodonta*): M128(263–264) ..	SPHTM			
crassinervis Mall. (*Asteia*): M71(232–233) ..	C'bury M			
crassinervis Mall. (*Ceratomerus*): M83(428–429) ..	USNM			
crassitarsus Mall. (*Chilocryptus*): M112(189) ..	Bishop M		3 USNM	
cribellata Bez. (*Stomatorhinia*): M36(334)				
cribripennis (Bez.) (*Epicerella*): M53(15–16, 26)	SPHTM	SPHTM		
crocea Mall. (*Perrissina*): M119(184–185)	Cawthron		2 USNM	
crockeri Curran (*Homoneura*): M133(143)				
crockeri Curran (*Rhabdochaeta*): M124(463); M126(228)				
crux Bez. (*Staurella*): M124(443)				
ctenophora Bez. (*Pygophora*): M58(160)				
cucumis French (*Dacus*): M81(256); M124(412)				1 Malloch USNM
cucurbitae Coq. (*Dacus*): M81(257)				
cupreus Hutt. (*Anabarrhynchus*): M90(242)				

* The specimen in USNM is labelled a paratype but is not mentioned in the original description.

† Type is labelled *L. confluens*, as is also the paratype in USNM.

‡ 1♀, Blundell's, F.C.T., 23.3.30 (I. M. Mackerras) (USNM). Mislabelled in Malloch collection as a paratype of *O. albohalterata* (*convergens* is a peculiarly distinct species, figured by Malloch). This is probably the *convergens* paratype from Blundell's, 23.iii.30, and Malloch's listing of L. F. Graham as collector was either a complete lapsus, or applied only to the specimen or specimens collected on March 15.

cuprina Wied. (*Lucilia*): M36(321)				34 Paramonov SPHTM
curvinervis (Bez.) (*Anomoia*): M124(449); M126(275)				
curvinervis Stenhammar (*Leptocera*): M106(325)				
curvinervis (Bez.) (*Nicholsonia*): M53(17–18, 31)	SPHTM			
curvinervis (Bez.) (*Phagocarpus*) (*Pseudospheniscus*): M127(241)				
curvipennis Frogg. (*Dacus*): M81(255)				
curvipes Hutt. (*Coelopa*): M101(345)				
curvipes Latr. (*Sphaerocera*): M24(85)				1 Malloch SPHTM
cyanea (Guér.) (*Angitula*): M122(170)				
cyaneomarginata Macq. (*Lucilia*): M36(320–321) ..				
cyclops Mall. (*Cleitamia*): M121(110)..	BM (NH)		2 BM (NH)	
cyclops Mall. (*Waterhouseia*): M115(261)	SPHTM			
cygnus Mall. (*Senostoma*): M114(15)	SPHTM			
cyprinus (de Meij.) (*Cephaloconus*): M109(89–90); M115(261); M125(429); M133(145)				
czernyi Duda (*Leptocera*): M106(325)				
dacoides (Walk.) (*Achiosoma*): M121(130)				
dactylopivora Mall. (*Chaetoleucopsis*): M86(216–217)	NSW Dept Agric		1 USNM	
**darwini* Mall. (*Actia*): M55(334); M68(308) ..	SPHTM	SPHTM		2 Malloch USNM
dasypleura Mall. (*Lasiopleura*): M43(303); M128(270)	SPHTM			
daveyi Knab & Mall. (*Microdon*): M1(233–235) ..	USNM		2 USNM	
deansi Mall. (*Apteroscinis*): M83(407–408) ..	C'bury M		1 USNM	
debeauforti (de Meij.) (*Acanthoneura*): M124(464)				
debilis (Hutt.) (*Limnohelina*): M72(302)				5 Malloch C'bury M; 1 Malloch USNM
deceptiva Mall. (*Hylemyia*): M4(428–429); M17(139); M72(291)	BM (NH)	BM (NH)	1 BM (NH)	12 Malloch, 1 F. van Emden BM (NH); 17 Malloch USNM; 4 Malloch SPHTM
decipiens Stein (*Dichaetomyia*): M58(172)				
decolor Mall. (*Lamprogaster*): M121(144)	SPHTM			
decora Macq. (*Duomyia*): M57(510)				
defecta Mall. (*Erythronychia*): M97(448)	C'bury M		1 USNM	
defecta Mall. (*Hythea*): M25(327–328)	SPHTM			2 Wirth as *Zeros defectus* USNM
deferens Mall. (*Calobates*): M110(346–348) ..	BM (NH)		5 USNM; 27 BM (NH)	
delandi Mall. (*Cleitamia*): M121(111)	SPHTM			
delicatula Mall. (*Prochaetops*): M112(186–187) ..	Bishop M		3 USNM	
demissa (Hutt.) var. *demissa* Hutt. (*Pollenia*): M72(322)				4 Malloch USNM
demissa var. *minor* Mall. (*Pollenia*): M72(323) ..	C'bury M		2 USNM (1 fragmentary)	
demissa var. *cuprea* Mall. (*Pollenia*): M72(323) ..	U S N M (badly damaged)		2 USNM	
dentipes Macq. (*Celetor*): M57(506)				
depressa Mall. (*Neotachina*): M119(244)	Cawthron			
depressifrons Mall. (*Euprosopia*): M129(86–88) ..	BM (NH)	BM (NH)	1 USNM; 6 BM (NH)	1 Malloch Aust. M
desvoidyi Aldrich (*Palpostoma*): M37(339)				
desvoidyi Guér. (*Rutilia*): M37(346–347); M44(332, 334); M55(302–303)				
dichromata Walk. (*Sapromyza*): M34(21–22) ..				1 Tonnoir USNM
didymoides Hend. (*Blassogaster*): M121(117)				
didymus (Ost.-Sack.) (*Blassogaster*): M121(116) ..				1 Malloch SPHTM
difficilis Mall. (*Platytachina*): M119(215–216) ..	Cawthron		1 USNM	
diffidens (Walk.) (*Orthellia*): M60(408)				4 Malloch USNM
difformis Brues (*Hypocera*): M2(433)				
dilata Mall. (*Botanobia*): M25(339); M134(58) ..	SPHTM	SPHTM	3 SPHTM	
dilatata Mall. (*Lispocephala*): M52(74)	Bishop M			
dimidiata Macq. (*Plecia*): M46(602)				
†*dimidiata* de Meij. (*Rivellia*): M121(121) ..				1 Malloch SPHTM; 1 Malloch USNM
dimorpha Mall. (*Arthuria*): M119(166–167) ..			2 USNM	
dimorpha Mall. (*Asteia*): M112(191–192)	Bishop M		3 USNM	
dimorpha Mall. (*Homoneura*): M98(35–36) ..	? Bruxelles			
discalis Walk. (*Brea*): M121(124)				
discalis Mall. (*Hyalomyia*): M67(95)	SPHTM			
discifera Hend. (*Brea*): M121(124)				
discifera de Meij. (*Euxestomoea*): M121(106)				
discordalis Bez. (*Neotoxura*): M53(9, 23)	SPHTM			
discolor Mall. (*Lioscinella*): M134(52)	SPHTM	SPHTM	1 ? SPHTM; 2 USNM	
discolor Fabr. (*Stomatorhinia*): M36(334)				1 Malloch, 2 Austen SPHTM
dispar Macq. (*Calliphora*): M36(312)				
dispar Macq. (*Winthemia*): M110(358)				
dissimilis Mall. (*Quadra*): M68(343)	CSIRO		1 USNM	
distincta Tonn. & Mall. (*Allophylopsis*): M39(98)..	C'bury M			1 Malloch USNM
distincta Kert. (*Homoneura*): M133(141)				
distinctus Mall. (*Dacus*): M81(259)..	BM (NH)			1 F. van Emden BM (NH)
distinctus Ric. (*Ommatius*): M56(408–409).. ..				6 Malloch USNM
distorta (Walk.) (*Neosophira*): M124(414)				

* The two specimens determined by Malloch in USNM are labelled "paratypes". These are recorded in M68(308) (Sydney, March 1921 and 26:1:1921) and so cannot be true paratypes. The allotype was, however, described in this later paper.

† Specimen in SPHTM determined by Malloch is more in agreement with the description of *R. conneza* Hendel

**divergens* Mall. (*Limnophora*): M22(328) ..	SPHTM			3 Malloch USNM
diversa Mall. (*Homoneura*): M133(143)	BM (NH)			
diversa Tonn. & Mall. (*Neolimnia*): M48(167) ..	Cawthron			
diversa Mall. (*Winthemia*): M68(348–349) ..	SPHTM			1 Malloch BM (NH)
diversifrons de Meij. (*Achias*): M121(136)				
†*diversipennis* Mall. (*Perissoneura*): M96(207–208)	Bishop M		46 Bishop M; 15 USNM	
diversipes Mall. (*Oscinosoma*): M83(414)	C'bury M			
doclea (Walk.) (*Pogonortalis*): M69(429); M121(120)				
doddi Ferg. (*Graptomyza*): M109(87)				1 Malloch SPHTM
doddi Ric. (*Promachus*): M46(610)				
doddi Curran (*Prosena*): M85(131)				
dohrni Dahl. (*Diploneura*): M110(331)				
domestica Linné (*Musca*): M58(174); M72(305); M95(203)				5 Patton, 1 Bezzi, 1 Hill SPHTM
dorsalis Mall. (*Apalpus*): M55(318)	CSIRO			
dorsalis Wandolleck (*Chonocephalus*): M110(339–340)				
dorsalis Macq. (*Prosena*): M67(116)				
dorsatus Collin (*Ceratomerus*): M83(428)				1 Malloch USNM
‡*dorsovittata* Mall. (*Limnohelina*): M72(300) ..	C'bury M	C'bury M	1 C'bury M; 3 USNM	2 Malloch DEI
dubia Mall. (*Batrachomyia*): M128(265)	SPHTM		1 ? CSIRO	
dubia Mall. (*Discocerina*): M106(320–321) ..	BM (NH)			
dubia Mall. (*Platensina*): M124(459)	SPHTM			
dubia Mall. (*Stilbomyella*): M108(76)	SPHTM		3 USNM	
dubia Mall. (*Trypanea*): M83(401)	C'bury M			1 F. A. Perkins BM (NH)
dubiosa Tonn. & Mall. (*Neolimnia*): M48(168) ..	Cawthron			
dubiosa Tonn. & Mall. (*Poecilohetaerella*): M34(25)..	C'bury M			
dubitalis Mall. (*Amenia*): M37(343); M67(101); M99(76)	USNM			
dubitalis Mall. (*Euprosopia*): M121(149)	BM (NH)	SPHTM		
§*dubitalis* Mall. (*Exechopalpus*): M67(132) ..	SPHTM		? ♂ USNM	
dubitata Mall. (*Rutilia*): M55(303–304)	Aust. M			34 D. J. Clark BM (NH)
dubium Mall. (*Calcager*): M119(175)	Cawthron			
duplicata Mall. (*Parahippelates*): M12(621) ..	S.A. Mus.			
duplicata (Mall.) (*Lasiopleura*): M12(621); M128(272)				
dux Eschscholz (*Chrysomyia*): M20(639); M72(315)				
efferata (Hutt.) (*Cerosomyia*): M119(198) ..				1 Malloch USNM
egmonti Hutt. (*Peremptor*): M97(453–454); M119(205)				
¶*eidsvoldensis* Mall. (*Sapromyzosoma*): M25(321) ..	SPHTM		1 SPHTM (headless); 1 USNM	
||*eidsvoldica* Mall. (*Lispa*): M22(336–337) ..	SPHTM		3 USNM	
elegans Macq. (*Chrysopasta*): M67(105–106) ..				7 Malloch USNM; 3 Malloch, 2 Paramonov SPHTM
elegans Mall. (*Dichaetomyia*): M50(468–469) ..	BM (NH)		1 BM (NH)	
elegans Tonn. & Mall. (*Huttonina*): M48(177–178)..	Cawthron		1 USNM	
elevata Fabr. (*Paralauxania*): M30(32–33); M38(411)				1 Malloch SPHTM; Tasmanian spec., M38(411) USNM
elongata Wulp (*Lamprogaster*): M57(515); M69(432); M121(144)				1 Malloch SPHTM; 2 Malloch USNM
elongata Mall. (*Limnina*): M44(327–328)				
elongatus Macq. (*Stenopogon*): M46(608)				
elstoni Mall. (*Oscinis*): M116(344)	CSIRO		1 USNM; 1 SPHTM; 3 CSIRO	
elzneri (Town.) (*Sturmia*): M55(330–331)				1 Malloch USNM
emmesia Mall. (*Conioscinella*): M128(285) ..	SPHTM		3 SPHTM; 2 USNM	
emmesia Mall. (*Cuphocera*): M68(318)	SPHTM			
enderbyi (Hutt.) (*Hydrellia*): M34(15)				
***enderleini* Hend. (*Plagiostenopterina*): M121(114); M129(68)				2 Malloch SPHTM
enigma Mall. (*Drosophila*): M35(6)	SPHTM			
ensifer Bez. (*Maenomenus*): M53(6)	SPHTM	SPHTM		
erasa Mall. (*Scotinosoma*): M121(117–118) ..	USNM	USNM		
erebea Skuse (*Plecia*): M46(602)				
erichsoni Engel (*Rutilia*): M37(348); M44(333); M55(297)				1 Malloch Aust. M; 1 Malloch USNM
erinaceus Hend. (*Themarohystrix*): M124(422)				
††*errans* Mall. (*Drosophila*): M106(301); M111(21–22); M112(193–194)				12 Malloch BM (NH)
erratica Mall. (*Coenolispa*): M94(194–195) ..	Bishop M		2 USNM; 3 Bishop M	

* The three determined specimens in USNM are wrongly labelled paratypes.

† The paratypes are actually dated November 19, 1930.

‡ The Mt. Arthur paratype should read Dec. 27, not 17, the date being partly obscured by the pin.

§ In USNM there is a male specimen from Tammin, W.A., 31 Aug. 1926, E. W. Ferguson. Malloch's handwritten label says "*Exechopalpus atripes* Paratype" but *atripes* (M67, p. 131, but published as *nigripes* on p. 132) was based on a single female from Sydney. The labelling appears to be a lapsus on the part of the author, and the specimen is probably the male paratype of *E. dubitalis*, with which it agrees in data and description.

¶ The whole series consisting of type and two paratypes was found in the Malloch Collection. All are females and all were on the same mount, the type not being identified. The best specimen has been arbitrarily marked "Lectotype" (C.W.S.).

|| Type is labelled *L. eidsvoldae*.

** One specimen in SPHTM determined by Malloch seems to be *P. aenea* Wied.

†† This is a name proposed elsewhere by Malloch for *D. similis* Lamb.

erratum Hend. (*Scaptomyzella*): M96(220–221)				
erythrocephala (Meig.) (*Calliphora*): M20(640); M36(314); M72(316)				3 Malloch, 3 Taylor SPHTM; 2 Malloch USNM
escheri (Bez.) (*Oedaspoides*): M124(452)				
ethelia Curran (*Minettia*): M133(144)				
ethoda Walk. (*Rutilia*): M55(303)				1 Malloch Aust. M
eucalypti Mall. (*Fergusonina*): M86(314–315) ..	SPHTM		1 USNM	1 Malloch USNM (no locality label)
eucosmae Bez. (*Actia*): M54(116); M68(307); M77(130)				2 Malloch USNM
eudypti (Hutt.) (*Xenocalliphora*):) M20(639); M72(318)				3 Malloch USNM
evanescens Collin (*Gynatoma*): M83(426)				
evitta Mall. (*Elassogaster*): M121(116)	SPHTM			
excellens Stein (*Heliographa*): M29(508)				
excepta Mall. (*Cleitamia*): M121(111)	BM (NH)		9 BM (NH)	
excepta Mall. (*Drosophila*): M106(308–309) ..	BM (NH)			
excepta Mall. (*Lioscinella*): M134(50–51)	USNM	USNM	1 USNM	
**excisa* (Thoms.) (*Atherigona*): M14(185); M28(115); M58(158); M60(396); M95(201)				1 Malloch SPHTM; 1 Malloch Bishop M
excisa var. *flavipalpis* Mall. (*Atherigona*): M49(303); M95(201)	? Amsterdam			2 Malloch Bishop M; 1 Malloch USNM
excisa var. *trilineata* Stein (*Atherigona*): M95(201)..				3 Malloch Bishop M; 2 Malloch USNM
excisa Kert. (*Lonchaea*): M43(306)				
exigua de Meij. (*Lyperosia*): M89(506)				6 Hill SPHTM
exiguus Collin (*Ceratomerus*): M83(428)				
exquisita Mall. (*Lasiopleura*): M128(270–271) ..	SPHTM		1 SPHTM	
extensa Mall. (*Heteria*): M72(329)	C'bury M			
extensa Mall. (*Trypanea*): M83(402)	C'bury M		2 USNM	1 F. A. Perkins BM (NH)
extremitata Mall. (*Lioscinella*): M134(55)	SPHTM		1 SPHTM	
exul (Curran) (*Neothemara*): M124(433); M126(254)				1 Malloch USNM
facialis Coq. (*Dacus*): M81(263)				
facialis Curran (*Prosena*): M85(131–132) ..			2 SPHTM	
fallax Hardy (*Calliphora*)			2 SPHTM	2 Malloch SPHTM
fasciata Stein (*Heliographa*): M29(508); M58(167)				
fasciatus Macq. (*Sumpigaster*): M67(110)				1 Malloch USNM
†*fascifacies* Mall. (*Rubaulia*): M124(422); M126(258)	BM (NH)	BM (NH)	17 BM (NH); 1 SPHTM	2 Malloch SPHTM; 2 Malloch USNM
fascigera Mall. (*Tephritis*): M83(391–392)	C'bury M		5 USNM	7 F. van Emden, 1 F. A. Perkins BM (NH)
fascipennis Mall. (*Eupsilopa*): M106(316–317) ..	BM (NH)			
fascipennis Mall. (*Guamomyia*): M135(207) ..	USNM		4 USNM	
fascipennis de Meij. (*Laglaisia*): M121(112–113)				
fasciventris Mall. (*Cadrema*): M128(278)	SPHTM			
fasciventris Mall. (*Pseudoleucopis*): M25(335); M70(490)	Lost SPHTM		1 probable SPHTM; 1 USNM	Cronulla ♂ M25(335) USNM
fatuhivae Mall. (*Heterodoxa*): M96(214–215) ..	Bishop M			
federata Mall. (*Oscinis*): M116(341)	CSIRO			
femoralis Mall. (*Hecamede*): M71(245); M111(11)..				1 Malloch USNM
‡*femoralis* Mall. (*Scaptomyza*): M110(*a*)(95) ..	Bishop M	USNM		
femorata Tonn. & Mall. (*Helosciomyza*): M48(161–162)	Cawthron		1 USNM	1 F. van Emden BM (NH)
fenestralis (Fall.) (*Decothea*): M39(86); M103(184)				
fenwicki Mall. (*Plethochaetigera*): M119(192–193)	USNM	USNM	3 USNM	
fenwicki Mall. (*Trypanea*): M83(404)	C'bury M			
fergusoni Bez. (*Actia*): M54(116); M68(304–305)..				1 Malloch SPHTM; 6 Malloch USNM
fergusoni Mall. (*Aenigmetopia*): M69(447).. ..	SPHTM	USNM		
fergusoni (Mall.) (*Cadrema*): M38(438); M128(278)				
fergusoni Mall. (*Froggattimyia*): M104(4–5) ..	SPHTM			
fergusoni Mall. (*Hippelates*): M38(438)				
§*fergusoni* Mall. (*Homoneura*): M38(420); M44(320)	SPHTM			4 Malloch USNM
fergusoni Patton (*Lucilia*) (*Hemipyrellia*): M36(320)				3 Malloch USNM; 6 Malloch, 1 Taylor SPHTM
fergusoni Mall. (*Myothyria*): M68(339–340).. ..	SPHTM		1 SPHTM; 2 USNM (1 headless)	
fergusoni Mall. (*Phaonia*): M17(141–142)	Aust. M			2 Malloch USNM
ferruginata Stenhammar (*Leptocera*): M106(324); M111(23)				
ferruginea Brunetti (*Apiochaeta*): M110(334)				
ferruginea Hend. (*Helosciomyza*): M7(228); M24(81)				1 Malloch USNM
ferruginea Lamb (*Rhicnoessa*): M111(18)				
ferruginea Hend. (*Rivellia*): M121(121)				
ferruginea Mall. (*Wattia*): M119(162–163) ..	USNM			
ferruginosa Wied. (*Chrysopilus*): M88(116)				
filifera Bez. (*Lonchaea*): M43(307); M74(241) ..				1 Malloch SPHTM; 2 Malloch USNM

* One specimen in SPHTM determined by Malloch is *A. excisa* var. *flavipalpis*.

† There are two specimens in USNM called "paratypes", but neither fits the published data: Solomon Is., Tulagi, 10:ii:1935 (R. A. Lever), and Guadalcanal, Lunga, 31:x:1935 (R. A. Lever).

‡ The type carries two labels. One calls it *Marquesia femoralis*. When originally examined in Malloch's collection the original label bearing the published name was folded up. "Marquesia femoralis Type" was written on the second label.

§ Malloch gave this name to two species, see descriptions M38(420) and M44(320). The latter requires renaming. The four determined specimens in USNM are incorrectly labelled paratypes.

flavalpis Macq. (*Actina*): M45(364)				
flava (Edw.) (*Sophira*): M126(257); M124(430–431)				1 Malloch USNM
flavescens Hend. (*Acropygrota*): M53(15)				
flavibasis Mall. (*Heteria*): M72(330)	USNM			
flavicans Mall. (*Myiospila*): M5(237–238) ..	BM (NH)			1 Malloch BM (NH); 2 Malloch USNM
flavicaudus Mall. (*Ommatius*): M56(409–410) ..	USNM	USNM	4 USNM	
flaviceps Hend. (*Asyntona*): M121(122); M129(76)				2 Malloch SPHTM; 1 Malloch USNM;
**flaviceps* (Macq.) (*Chlorotachina*): M37(353); M55(324)				1 Malloch, 2 Paramonov SPHTM; 1 Malloch Aust. M; 8 Malloch USNM
flaviceps Mall. (*Incurviseta*): M38(405)	CSIRO			
flaviceps Mall. (*Themarohystrix*): M124(422–423)	SPHTM		1 USNM	
flavicollis Ferg. (*Graptomyza*): M109(87)				1 Malloch SPHTM
flavicornis Mall. (*Anatropomyia*): M67(127) ..	SPHTM			
flavicornis Mall. (*Apactoneura*): M73(223–224) ..	Bishop M		1 BM (NH)	
flavicornis Mall. (*Batrachomyia*): M25(336); M128(264)	SPHTM			
flavicornis Mall. (*Fergusonina*): M24(92); M86(215)	CSIRO			
flavicornis Mall. (*Lucilia*): M36(322)	CSIRO (abdomen damaged)			1 Malloch SPHTM
flavicornis Mall. (*Semisuturia*): M37(341) ..	USNM			
flavifacies Mall. (*Bunostoma*): M96(219–220) ..	Bishop M	Bishop M	4 Bishop M; 3 USNM	
flavifrons Tonn. & Mall. (*Achrostichalia*): M39(87); M103(199–202)	Cawthron			
flavifrons (Macq.) (*Cylindromyia*): M53(291); M68(315)				1 Malloch SPHTM; 4 Malloch USNM
flavifrons Mall. (*Doddiana*): M68(342); M100(137)	SPHTM			
flavifrons Aldr. (*Microcalliphora*): M36(326) ..				1 Malloch SPHTM
†*flavifrons* (Tonn. & Mall.) (*Prosopantrum*): M103(199–202)				3 Malloch BM (NH)
‡*flavimana* Mall. (*Adrama*): M123(333)	USNM			
flavinana Mall. (*Sapromyza*): M30(42–43) ..	SPHTM		1 USNM	1 Malloch USNM
flavinceris Miller (*Hilara*): M83(427)				1 Malloch USNM
flavipalpis Mall. (*Incurviseta*): M38(407)	CSIRO		2 USNM; 1 CSIRO	
flavipalpis Mall. (*Paralauxania*): M38(412) ..	SPHTM	USNM		
flavipennis (Macq.) (*Amphibolosia*): M68(310–311)				
flavipennis Macq. (*Formosia*): M37(350); M55(309)				1 Malloch SPHTM; 1 Malloch USNM
flavipennis Macq. (*Lamprogaster*): M45(349) ..				2 Malloch USNM
flavipennis Mall. (*Paralauxania*): M38(410–411)..	CSIRO			
flavipes de Meij. (*Brea*): M121(124)				
flavipes Mall. (*Caviceps*): M19(356); M38(442); M128(275)	SPHTM			
flavipes B. & B. (*Rutilia*): M55(306); M67(109) ..				3 Malloch USNM
flaviseta Mall. (*Conioscinella*): M128(286–287) ..	SPHTM		4 SPHTM; 4 USNM	
flaviseta Mall. (*Tricimba*): M83(409–410) ..	C'bury M	USNM		
flavitarsis Tonn. & Mall. (*Clasiopa*): M34(13) ..	C'bury M			
flavitarsis Mall. (*Microtropeza*): M55(288); M67(100)	Aust. M			2 Malloch USNM
flavitarsis Mall. (*Pseudoleucopis*): M24(93); M70(490)	SPHTM			Specimen M70(490) USNM
flavitarsis (Macq.) (*Pseudorichardia*): M63(100); M73(222); M96(206)				
flaviventris Mall. (*Microtropeza*): M67(101).. ..	CSIRO			
flaviventris Mall. (*Spilogona*): M83(379–380) ..	C'bury M	C'bury M	2 USNM	
flavoapicalis Mall. (*Oscinosoma*): M83(411–412) ..	USNM		1 USNM	
flavocapitata Mall. (*Lioscinella*): M134(55) ..	SPHTM		1 SPHTM	
flavocentralis Watt (*Agromyza*): M38(427) ..				2 Malloch USNM
flavodorsalis Mall. (*Sapromyza*): M38(418) ..	CSIRO	USNM		
flavofemorata Mall. (*Homoneura*): M38(420–421) ..	CSIRO	USNM		
flavofemorata Mall. (*Medinella*): M119(236) ..	C'bury M		2 USNM	4 Malloch USNM
flavofusca Mall. (*Helina*): M17(143); M23(42) ..	Aust. M			2 Malloch USNM
flavohalterata Mall. (*Leucophenga*): M25(334–335)..	USNM		1 USNM	
§*flavohirta* Mall. (*Dichaetomyia*): M22(326) ..	USNM	USNM	3 USNM; 2 SPHTM	1 Malloch SPHTM
flavohirta Mall. (*Drosophila*): M19(354)	SPHTM		6 USNM; 4 SPHTM	
flavohirta Mall. (*Lasiocalypter*): M67(121) ..	SPHTM		4 USNM	
flavohirta Mall. (*Macquartia*): M119(222)	C'bury M		2 USNM	
flavohumeralis Mall. (*Botanobia*): M134(60) ..	CSIRO			
flavolateralis Mall. (*Limnophora*): M58(167–168) ..	BM (NH)		7 BM (NH)	
¶*flavolateralis* Mall. (*Lioscinella*): M134(53) ..				2 Malloch USNM
flavomarginata Mall. (*Neohelina*): M22(329–330)	Aust. M		1 USNM	
flavoscutellata Mall. (*Hemilea*): M126(270) ..	BM (NH)		4 BM (NH)	
flavoscutellata Mall. (*Stomosis*): M24(88–89) ..	SPHTM			
flexinervis Stein (*Atherigona*): M14(192–193)				
formosa Mall. (*Neothemara*): M124(433); M126(255)	BM (NH)			
formosa R.-D. (*Rutilia*): M37(347–348); M44(332); M55(295)				4 Malloch USNM; 1 Engel, 12 Paramonov SPHTM; 2 Malloch Aust. M

* One specimen in SPHTM determined by Malloch is labelled *C. fulviceps* Macq.

† A reference to New Zealand specimens is to be found in a footnote by F. W. Edwards in Malloch, 1933, Diptera of Patagonia and South Chile (*Brit. Mus. (Nat. His.)*), Part VI, fasc. 4, p. 201.

‡ Although described in an Australian journal, this species is from North Borneo.

§ A ♀ paratype in SPHTM (Townsville, G. F. Hill) is not recorded as such by Malloch.

¶ Of the two specimens in USNM one is marked " Type " but they are from Sydney, 23:i:25. The specimens do not agree with the descriptions so are not the types.

formosa var. *subvittata* Mall. (*Rutilia*): M55(295) ..	Aust. M			
formosina Curran (*Rutilia*): M78(78)				
formosipennis (Walk.) (*Neothemara*): M124(434); M126(254–255)				1 Malloch SPHTM; 1 Malloch USNM
frauenfeldi Sch. (*Dacus*): M81(259); M126(232)..				2 Malloch USNM
frit (Linné) (*Oscinella*): M128(287–288)				1 Malloch SPHTM
frit Linné (*Oscinosoma*): M83(407)				
**froggatti* Mall. (*Botanobia*): M134(60–61).. ..	CSIRO			
froggatti Town. (*Chlorodexia*): M47(653)				10 Malloch USNM
froggatti Town. (*Chlorotachina*): M55(326) ..				1 Malloch Aust. M
froggatti Bez. (*Dacus*): M81(257); M124(413); M126(241)				1 Malloch SPHTM
froggatti Tayl. (*Sarcophaga*): M75(482)	SPHTM	SPHTM		1 Hill, 2 Parker SPHTM; 1 Malloch USNM
frontosa Mall. (*Formosia*): M55(310–311)	Aust. M		1 Aust. M; 1 Vienna	
fuliginosa Hend. (*Pterogenia*): M121(126)				
fulva (Hutt.) (*Allophylopsis*): M39(98–99) ..				3 Malloch USNM
fulva Mall. (*Tapeigaster*): M31(553); M69(436) ..	USNM		1 USNM	1 Malloch SPHTM
fulvescens Mall. (*Australosepsis*): M25(314–315); M43(307)	SPHTM		3 SPHTM; 1 USNM	3 Hendel BM (NH)
†*fulvescens* var. *atratula* Mall. (*Australosepsis*): M25(315)	SPHTM	SPHTM	5 SPHTM	2 Malloch USNM
fulvescens Mall. (*Dasyrhicnoessa*): M109(93–94) ..	SPHTM		1 USNM	
fulvescens Mall. (*Rivellia*): M129(72)	BM (NH)		1 BM (NH)	
fulviceps de Meij. (*Achias*): M121(134)				
fulviceps Mall. (*Paralauxania*): M30(33); M38(411)	SPHTM			1 Ferguson SPHTM; 6 Malloch USNM
fulvicollis Fabr. (*Plecia*): M46(604)				
fulvicoxa Hardy (*Calliphora*): M84(64–65) ..			2 SPHTM	
fulvifrons (Hutt.) (*Tethinosoma*): M72(335–336) ..				4 Malloch USNM
fulvipes Hutt. (*Cerosomyia*): M119(199)				2 Malloch USNM
fulvipes Mall. (*Exechopalpus*): M67(132)	SPHTM			
fulvipes Mall. (*Lamprogaster*): M121(145) ..	SPHTM			
fulvithorax Mall. (*Gordonia*): M31(554)	SPHTM			1 Malloch USNM
fulvithorax Mall. (*Pectiniseta*): M58(163)	Bishop M		1 BM (NH)	
fulvofemoralis Mall. (*Pogonortalis*): M135(205) ..	USNM	USNM	2 Bishop M	
fulvoventris Meig. (*Masicera*): M110(357–358)				
fulvoviridis Mall. (*Incurviseta*): M38(407) ..	CSIRO			
‡*fumicosta* Mall. (*Dichaetomyia*): M58(172) ..	USNM	USNM	3 BM (NH); 1 USNM	
fumicosta var. *hirta* Mall. (*Dichaetomyia*): M58(173)	BM (NH)			
fumicosta var. *savaii* Mall. (*Dichaetomyia*): M58(173)	Bishop M		1 BM (NH)	
fumicosta Mall. (*Neoeuxesta*): M73(218)	BM (NH)			
fumicosta Mall. (*Spilogona*): M83(380–382) ..	C'bury M	C'bury M	1 USNM	
§*fumifrons* Mall. (*Sapromyzosoma*): M25(322) ..				1 Malloch SPHTM
fumosa (Hutt.) (*Pollenia*): M20(639); M72(321)				5 Malloch USNM
fumosum (Hutt.) (*Pollenia*): M20(639)				
furcata Tonn. & Mall. (*Huttonina*): M48(175–176); M72(343)	Cawthron		1 USNM	
furcata Kert. (*Monocera*): M133(135)				
furcata Mall. (*Senostoma*): M114(14)	CSIRO		1 USNM	
furcatus Hend. (*Achias*): M121(136)				
furcatus Aldr. (*Hyleorus*): M55(334)				
fusca Mall. (*Lispocephala*): M52(85)	Bishop M			
¶*fusca* Mall. (*Prochaetops*): M91(6); M112(182) ..	Bishop M			Specimen M112(182) USNM
fusca (Thoms.) (*Rivellia*): M121(121); M129(71)				
fuscibasis Mall. (*Lamprogaster*): M69(433–434) ..	SPHTM	USNM		
fuscicauda Boettcher (*Sarcophaga*): M75(483) ..				4 Parker SPHTM
fuscifacies (Walk.) (*Euprosopia*): M121(151) ..				1 Malloch Aust. M
fuscifrons Mall. (*Trigonometopus*): M31(550–551); M59(34)	USNM			
fuscimana Mall. (*Notiphila*): M25(326–327) ..	SPHTM			
fuscipalpis Mall. (*Lispa*): M58(155)	BM (NH)			
fuscipennis Tonn. & Mall. (*Allophylopsis*): M39(97–98)	Cawthron			
fuscipes Mall. (*Parahippelates*): M18(330) ..	Aust. M		2 SPHTM; 2 USNM	
fuscipes (Mall.) (*Lasiopleura*): M18(330); M128(274)				
fuscipes Mall. (*Tricimba*): M83(410)	C'bury M		1 USNM	
fusciseta Mall. (*Lispocephala*): M52(86)	Bishop M			
fuscithorax Mall. (*Drosophila*): M19(353–354) ..	SPHTM			
fusciventris Macq. (*Actina*): M45(364)				
fuscoapicata Mall. (*Adrama*): M126(249–250) ..	BM (NH)		1 BM (NH)	1 F. van Emden BM (NH)
fuscoapicata Mall. (*Dioides*): M133(134)	BM (NH)			
fuscobrunnea Mall. (*Lispocephala*): M52(80) ..	Bishop M			
fuscocalyptrata Macq. (*Hydrotaea*): M13(668)				
fuscocostata Mall. (*Sapromyza*): M25(319) ..	SPHTM		1 USNM	
fuscofacies Mall. (*Lispocephala*): M52(83) ..	Bishop M			
||*fuscofemorata* Mall. (*Calliphora*): M36(309–310) ..	CSIRO			2 Malloch SPHTM; ?1 D. Aubertin BM (NH)

* In CSIRO are three specimens on one pin labelled "Type" and another label "Holotype".
† The two determined specimens in USNM are incorrectly labelled paratypes.
‡ The paratype in USNM is the "one fragmentary paratype" from Apia, Samoa (Doane).
§ One specimen in SPHTM determined by Malloch is labelled *Homoneura fuscifrons* Mall.
¶ One specimen recorded by Malloch in M112(182) is labelled paratype but is just a subsequently recorded specimen.
|| The two specimens identified by Malloch now in SPHTM bear the same data as is given for the type. It is possible that Malloch omitted to write "Type" on the label of the specimen he originally described.

fuscoflava Mall. (*Helina*): M8(274–275); M11(574); M12(603); M23(42)	BM (NH)			2 Malloch SPHTM; 3 Malloch BM (NH); 2 Malloch USNM
fuscofrontata Mall. (*Conioscinella*): M128(283–284)	SPHTM		1 USNM	
fuscolimbata Mall. (*Sapromyza*): M30(45)	SPHTM	SPHTM	6 SPHTM; 2 USNM	
**fusifacies* (Walk.) (*Euprosopia*): M121(151)				
ganura Bez. (*Sarcophaga*): M62(270)				1 Malloch USNM
genalis Mall. (*Frontalia*): M53(29–30)	SPHTM			
geniculata Mall. (*Altaia*): M119(209–210) ..	Cawthron		3 USNM	2 Malloch USNM
geniseta Mall. (*Australina*): M25(323)	SPHTM	USNM		
geniseta Stein (*Chaetolispa*): M12(606)				
georgei Mall. (*Prodiaphania* or *Senostoma*): M55(292); M114(12)	Aust. M		1 Aust. M	1 Malloch SPHTM; 2 D. J. Clark BM (NH); 1 Malloch USNM
gestroi Kert. (*Cleitamia*): M121(109)				
glabella Bez. (*Fannia*): M58(156)				
glabra Tonn. & Mall. (*Huttonina*): M48(177) ..	Cawthron		2 USNM	
glauca (Thoms.) (*Trypanea*): M124(462–463) ..				1 Malloch SPHTM
glauca Thoms. (*Trypeta*): M124(462)				
goniaeformis (Macq.) (*Anamastax*): M54(114) ..				1 Malloch Aust. M
goniceps Hend. (*Dasyortalis*): M121(103)				1 Malloch SPHTM
gordoni Mall. (*Homoneura*): M35(13)	SPHTM			
gourlayi Mall. (*Microhystricia*): M119(177–178) ..	Cawthron		1 USNM	
†*gracilis* Mall. (*Chloromerus*): M38(432–433); M116(336)	SPHTM		1 USNM	
gracilis Hend. (*Lamprogaster*): M121(141)				
graminum Fall. (*Scaptomyza*): M96(220)				
grandis (Dol.) (*Antineura*): M121(104)				
granulosa Mall. (*Assuania*): M78(69–70)	SPHTM		1 SPHTM	
gratiosa de Meij. (*Mycodrosophila*): M106(286); M111(20)				
greyi Mall. (*Prosenosoma*): M119(189–190) ..	C'bury M			
grisea Mall. (*Delta*) (*Deltomyza*): M68(333) ..	CSIRO			
grisea Mall. (*Erythronychia*): M97(448–449) ..	Cawthron			
grisea Mall. (*Limnohelina*): M72(299–300) ..	C'bury M			
grisea Mall. (*Paropsivora*): M104(7–8)	CSIRO			
grisea Mall. (*Truphia*): M72(310–311)	C'bury M			
grisea Mall. (*Trypherina*): M119(219–220) ..	USNM		1 USNM	
‡*griseadorsalis* Mall. (*Sapromyza*): M30(45) ..	SPHTM			
griseopleura Mall. (*Conioscinella*): M128(282) ..	CSIRO	USNM		
griseovitta Mall. (*Lasiopleura*): M114(25); M128(272)	SPHTM			Specimen recorded in M128(272) USNM
grisescens Beck. (*Hecamede*): M111(11)				
grossa Mall. (*Chlorops*): M78(70); M116(339–340)..	SPHTM			
grossa de Meij. (*Homoneura*): M61(412)				
grossa Mall. (*Lamprogaster*): M121(142)	BM (NH)			
grossa (Mall.) (*Oscinis*): M116(339–340)				
grossiseta Beck. (*Assuania*): M78(69–70)				
guamae Mall. (*Rhabdochaeta*): M135(204)	USNM			
gurneyi Mall. (*Fergusonina*): M86(215–216) ..	SPHTM			
guttata Tonn. & Mall. (*Trypaneoides*): M34(20); M71(244)	C'bury M		1 USNM	1 Malloch USNM
guttipennis Macq. (*Epicerella*): M53(12)				
guttipennis Kert. (*Loriomyia*): M121(113)				
halterata Mall. (*Mycodrosophila*): M76(331–332); M111(20)	USNM			
handlirschi Hend. (*Rhagadolyra*): M38(413)				
hastata Mall. (*Diarrhegmoides*): M124(437–438) ..	SPHTM		1 USNM fragmentary)	
§*hawaiiensis* Mall. (*Homoneura*): M66(208); M112(189); M133(143)			4 USNM	8 Malloch BM (NH)
hendersoni Mall. (*Atherigona*): M14(184); M58(158)	BM (NH)		5 BM (NH); 4 USNM	1 Malloch BM (NH)
heterocera (Macq.) (*Tritaxys*): M54(113–114) ..				1 Malloch Aust. M
heterura Thoms. (*Trypeta*): M124(459–460)				
hieroglyphica Mall. (*Sapromyza*): M38(415–416) ..	SPHTM		1 USNM	
hilaris Hend. (*Mesoctenia*): M121(123)				
¶*hilli* Patton (*Calliphora*): M36(309); M84(64) ..				1 Malloch, 3 Taylor SPHTM; 14 Malloch USNM
||*hilli* Mall. (*Lispa*)	SPHTM			
hilli Mall. (*Lonchaea*): M43(306)				
***hirsuta* Mall. (*Fenwickia*): M72(338)	C'bury M		4 C'bury M; 4 USNM	
hirsuta (de Meij.) (*Lasionemopoda*) (*Sepsis*): M25(312–313); M43(307)				1 Malloch SPHTM; 5 Malloch USNM

* Specimen in Aust. M is labelled *E. fusicfacies*. The spelling in M121(151) is incorrect.
† The date on the USNM paratype is 26:11:22. This means Nov. 26, not Feb. 26 as Malloch read it.
‡ Type is labelled *S. grisea*.
§ Dr. E. H. Bryan has provided the following information. "This species had been previously described by Grimshaw in the Fauna Hawaiiensis 3 (2): p. 84, 1902, as *Sciomyza hawaiiensis*. The use of the specific name was a coincidence, for Malloch apparently had not been aware of the previous description. It remained for Dr. D. E. Hardy to point out the synonymy in Proceedings of the Hawaiian Entomological Society, vol. 14 (1): p. 73. Therefore the actual type of this species is in the British Museum, from material collected by Dr. J. C. L. Perkins. It is correctly *Homoneura hawaiiensis* (Grimshaw)." Malloch's original reference is omitted above. It is *Proc. Hawaiian Ent. Soc.*, vol. 6: 383. Notwithstanding the above, the types of Malloch's name have not been located.
¶ One of the specimens in USNM is identified as *Neopollenia hilli*.
|| Although a holotype exists to which this name is attached the name was not published. The type bearing this name is in reality a paratype of *Lispa incerta*. See under the latter for further details.
** The date on the specimen marked "Type" is actually Jan. 5–7, 1922.

hirsuta Hend. (*Lasioxiria*): M121(101)				
hirta Mall. (*Eustacomyia*): M67(133–134)	SPHTM			
hirta Town. (*Froggattimyia*): M55(323); M104(6)..				2 Malloch SPHTM
hirta Mall. (*Neoerythronychia*): M97(450–451) ..	Cawthron		2 USNM	
hirta Mall. (*Samoaia*): M106(275–276)	BM (NH)	BM (NH)	3 BM (NH)	
hirtibasis Mall. (*Helina*): M13(671–672); M23(41)	Aust. M	USNM	1 USNM	1 Malloch USNM
**hirticauda* Mall. (*Lasiocalypter*): M67(120–121) ..	SPHTM		2 USNM	3 Malloch USNM
hirticeps Mall. (*Erythronychia*): M97(446–447) ..	Cawthron		1 USNM	
hirticeps Mall. (*Geraldia*): M68(328)	SPHTM	USNM (headless)		
†*hirticeps* Mall. (*Pollenia*): M36(318–319); M114(21)	SPHTM		1 SPHTM; 2 USNM	2 Malloch SPHTM; 2 Malloch USNM
hirticeps Mall. (*Rutilia*): M55(305); M67(109) ..	Aust. M		1 Aust. M	1 D. J. Clark BM (NH); 1 Malloch USNM
hirticornis de Meij. (*Drosophila*) (*Hirtodrosophila*): M106(291)				
hirtifemur Mall. (*Lispocephala*): M52(77) ..	Bishop M			
hirtifemur Mall. (*Sepsis*): M25(314)	SPHTM			
hirtimana Mall. (*Pygophora*): M108(77)	? Lost SPHTM			
‡*hirtipes* Mall. (*Botanobia*): M134(63)	USNM		6 USNM	
hirtiventris Mall. (*Sapromyza*): M25(318–319) ..	SPHTM	USNM	1 USNM	3 Malloch USNM
§*hirtiventris* Mall. (*Scholastes*): M135(208) ..	Bishop M	Bishop M		2 Malloch USNM
hivaoae Mall. (*Heterodoxa*): M96(213–214) ..	Bishop M			
hivaoae Mall. (*Neohydrellia*): M111(14–15) ..	Bishop M		1 USNM	
hopkinsi Mall. (*Pygophora*): M58(161)	BM (NH)	BM (NH)	3 BM (NH)	
horni Hend. (*Callistomyia*): M124(447–448)				
hortensia (Wied.) (*Morellia*): M60(408) ..				
hortona (Walk.) (*Calliphora*): M46(613)				At least 6 Malloch USNM, some as *Calliphora*, some as *Xenocalliphora*
hortona (Walk.) (*Xenocalliphora*): M20(639); M72(317)				
horvathi (Kert.) (*Homoneura*): M133(142, 144) ..				1 Malloch SPHTM
howei Mall. (*Helina*): M13(671); M23(41); M55(283)	BM (NH)			1 Malloch Aust. M
hudsoni (Hutt.) (*Allophylopsis*): M39(96–97) ..				5 Malloch USNM
hudsoni Marshall (*Arctoneura*): M46(600)				
hudsoni Mall. (*Millerina*): M26(140–141); M72(293)	USNM		1 USNM	
humeralis (Hutt.) (*Erythronychia*): M97(443–444)				4 Malloch USNM
huttoni Mall. (*Evibrissa*): M83(386–388)	Cawthron			1 D. J. Clark BM (NH)
huttoni (Mall.) (*Hexamera*): M119(178)				
huttoni Mall. (*Limnohelina*): M72(296–297) ..	C'bury M			
huttoni Mall. (*Oscinosoma*): M83(411)	C'bury M		4 USNM	
huttoni Mall. (*Protohystricia*): M68(352–353); M97(432–433); M119(178)	USNM			
hyalinata Mall. (*Actia*): M110(364)	BM (NH)	BM (NH)		1 Malloch BM (NH)
hyalipennis Mall. (*Campylocera*): M53(30–31) ..	USNM			
hyalipennis Mall. (*Chaetopiophila*): M43(309); M80(293)	SPHTM			
hyalipennis Mall. (*Euxesta*): M96(209–210) ..	Bishop M		42 Bishop M; 15 USNM	
hyalipennis Mall. (*Isoclusia*): M66(200–201) ..	Bishop M			
hyalipennis Mall. (*Semisuturia*): M37(342) ..	BM (NH)			
hyalipuncta Mall. (*Trypaneoides*): M61(411) ..	Amsterdam			
hyalis Mall. (*Hyalomyia*): M67(96)..	USNM			
hydei Sturtevant (*Drosophila*): M12(616) ..				2 Malloch SPHTM
hypopleuralis Mall. (*Helina*): M23(43)	SPHTM			
hypopleuralis Mall. (*Myiospila*): M22(330–331) ..	BM (NH)		2 USNM	
hypopygialis Mall. (*Drosophila*): M106(307–308) ..	BM (NH)	? BM (NH)	22 BM (NH)	2 Harrison USNM
iceryae (Williston) (*Cryptochaetum*): M38(423) ..				2 Hardy SPHTM
illingworthana Bez. (*Adapsilia*): M53(16–17); M53(31)	SPHTM			1 Malloch USNM
illingworthi Aldr. (*Baliosutum*): M23(45–46)				
illingworthi Mall. (*Homoneura*): M35(14–15) ..	SPHTM	USNM		
illingworthi Aldr. (*Metallea*): M36(330); M55(283)				2 Malloch SPHTM; 1 Malloch Aust. M; 13 Malloch USNM
illocata Walk. (*Anthomyia*): M60(390)				
imitans Mall. (*Haplomyza*): M104(1–2)	SPHTM		4 USNM	2 Malloch SPHTM
imitans Mall. (*Heteromeringia*): M69(435) ..	DEI			
imitans Mall. (*Rivellia*): M73(220)	BM (NH)	BM (NH)	1 BM (NH)	
imitatrix Mall. (*Aneuria*): M72(340–341) ..	C'bury M		1 USNM	
imitatrix Mall. (*Caricea*): M22(333)	SPHTM		3 USNM	
imitatrix Mall. (*Helina*): M17(142–144); M23(41)..	SPHTM			
immaculata Mall. (*Scatella*): M25(331)	SPHTM		1 USNM	
immaculipennis Mall. (*Arnomyia*): M110(a)(93) ..	Bishop M		1 USNM	
immaculipennis Mall. (*Prochaetops*): M112(186) ..	Bishop M		1 USNM	
immaculipennis Frey (*Pygophora*): M60(395)				
immaculipes Mall. (*Sapromyza*): M30(41)	SPHTM			
¶*immaculiventris* Mall. (*Homoneura*): M133(140) ..	BM (NH)		1 BM (NH); 1 USNM	
immaculiventris Mall. (*Limnophora*): M58(166) ..	BM (NH)	BM (NH)		
immigrans Sturt. (*Drosophila*): M12(617).. ..				1 Malloch SPHTM; 3 Malloch USNM

* In Malloch's Collection, USNM, three other specimens, 2 ♂♂ of Jan. and 1 ♀ of Feb., stood with the two paratypes immediately after the Malloch paratype label, but are not noted in the description, unless perchance the female is the second female paratype.

† The allotype is one of the listed paratypes but was not differentiated by Malloch.

‡ The allotype lies undifferentiated among the paratype series.

§ The two determined specimens in USNM are incorrectly labelled paratypes, as they do not agree with the published data.

¶ The paratype in USNM could be the specimen published as allotype.

impar Stein (*Dichaetomyia*): M22(327)				1 Malloch SPHTM; 4 Malloch USNM
imperfecta Mal. (*Sturmia*): M110(353–354) ..	BM (NH)		1 SPHTM	
imperfecta Mall. (*Trypanea*): M83(403)	C'bury M			1 F. A. Perkins BM (NH)
imperialis R.-D. (*Amenia*): M37(343); M67(101); M99(75)				12 Malloch USNM; 8 Paramonov SPHTM
imperialis Guér. (*Rutilia*): M44(333, 335); M55(297)				1 Malloch Aust. M; 2 Malloch USNM
impingens (Walk.) (*Euprosopia*): M121(151) ..				1 Malloch SPHTM
impressa Mall. (*Oscinis*): M116(342–344) ..	SPHTM			
**impura* (Beck.) (*Lioscinella*): M134(52)				2 Malloch SPHTM
inaequalis Mall. (*Cyclopsia*): M124(445)	BM (NH)			
incana Meig. (*Scaptomyza*): M96(219)				
†*incerta* Mall. (*Lispa*): M22(337–338)	Presumed SPHTM	Presumed USNM		8 Malloch BM (NH)
incertus Mall. (*Dacus*): M118(113–115)	Bishop M		4 USNM	
incidens Curran (*Calcageria*): M55(342); M119(172–173)				1 Malloch USNM
‡*incidens* var. *nuda* Mall. (*Calcageria*): M119(175)..			2 USNM; 1 Cawthron	
incisuralis Macq. (*Actina*): M45(364)				
incisuralis (Macq.) (*Chrysomyia*): M36(327) ..				3 Malloch, 4 Taylor SPHTM; 3 Malloch USNM
inconspicua Tonn. & Mall. (*Allophylopsis*): M39(95)	Cawthron			
inconspicua Mall. (*Rhamphella*): M69(449) ..				
inconspicua Mall. (*Voriella*): M68(336–337); M110(361)	SPHTM			
inconstans Mall. (*Lispocephala*): M52(85)	Bishop M	Bishop M		
§*indecisa* Mall. (*Homoneura*): M31(551)	SPHTM			1 Malloch USNM
indecisa Mall. (*Prosena*): M67(116); M85(131) ..			4 USNM; 6 SPHTM	
indistincta Mall. (*Lamprogaster*): M45(349) ..	USNM			
indistincta de Meij. (*Trypeta*): M124(464)				
inducta Walk. (*Lucilia*): M92(16)				
inermipes Mall. (*Grammicomyia*): M110(343–344)..	BM (NH)	USNM	1 BM (NH); 1 USNM	
inermis Mall. (*Doddiana*): M100(138–139) ..	SPHTM	USNM	1 BM (NH)	2 D. J. Clark BM (NH)
inermis Mall. (*Hecamede*): M111(12–13)	Bishop M		1 USNM	
inermis Mall. (*Xenognathus*): M73(228)	Bishop M	BM (NH)		
inexpletus Collin (*Homalocnemis*): M97(458) ..				3 Malloch USNM
infuscata Mall. (*Zealandotachina*): M119(231) ..	USNM			
innocua Mall. (*Euprosopia*): M121(152–153) ..	BM (NH)	BM (NH)	7 BM (NH)	
innocua Mall. (*Hirtodrosophila*): M106(294) ..	BM (NH)		1 BM (NH)	
inornata Mall. (*Drosophila*): M12(617)	Aust. M		1 USNM	2 Malloch USNM
inornata Guér. (*Rutilia*): M37(347); M44(331); M55(302)				3 Engel SPHTM; 1 Malloch Aust. M; 1 Malloch USNM
inscitus Hutt. (*Occisor*): M119(206)				1 Malloch USNM
insignificans Mall. (*Cadrema*): M83(404–407) ..	C'bury M	C'bury M	2+1 damaged USNM	
insignis de Meij. (*Acanthoneura*): M124(435); M124(464)				
insignis de Meij. (*Cleitamia*): M121(110)				
insignis Stein (*Heliographa*): M29(508); M58(167)				
insolita Walk. (*Polyara*): M124(418)				1 Malloch SPHTM; 1 Malloch USNM
instabilis Mall. (*Diploneura*): M110(330–331) ..	Bishop M		1 BM (NH)	
insulana Brues (*Megaselia*): M110(333)				
insularis Mall. (*Metallea*): M36(330–331)	SPHTM	USNM		
insularis Mall. (*Sigaloessa*): M76(321–322) ..	USNM	USNM		
insulicola Mall. (*Euprosopia*): M129(84–86) ..	BM (NH)		2 BM (NH)	
intensa Curran (*Paliana*): M68(345)				
intermedia Mall. (*Microtropeza*): M67(100–101) ..	CSIRO			1 D. J. Clark BM (NH); 2 Paramonov SPHTM
¶*interrupta* Bez. (*Pseudorichardia*): M96(206) ..				7 Malloch USNM
interrupta Mall. (*Zealandortalis*): M71(243–244) ..	C'bury M		1 USNM	
invalida Mall. (*Actia*): M68(305)	SPHTM		3 USNM	
iridescens Mall. (*Helina*): M9(139); M23(41) ..	BM (NH)			2 F. van Emden BM (NH); 1 Malloch SPHTM; 1 Malloch USNM
irregularis Mall. (*Duomyia*): M57(509–510) ..	DEI			

* One specimen in SPHTM labelled *L. impura* det. Malloch appears to be *L. varidorsata* Mall.

† No types bearing this name have been found. Four specimens from Eidsvold, 16.4.24, Bancroft, have been placed under this name in SPHTM but there is no indication of the authority for the identification. Apart from these the following specimens exist to which the name *Lispa hilli* is attached.

(i) Type ♀ G. F. Hill, Darwin, N.T. SPHTM
(ii) ♀ Paratype, Eidsvold, Q'ld } Both found together in USNM
(iii) ♂ Unlabelled, Eidsvold, Q'ld }

These specimens run to *L. incerta* in Malloch's key (M22(333–35)) and agree with the description. It seems apparent that *L. hilli* was published as *L. incerta* and the holotype is specimen (iii) above, and specimen (ii) is the allotype. Specimen (i) is probably one of the paratypes mentioned in the original description, as is also a further unlabelled specimen in SPHTM from Babinda, Q'ld (J. F. Illingworth, collector).

‡ This variety is not listed by Miller 1950 (Catalogue of the Diptera of the New Zealand Sub-Region) and it is possible that the type will still be found in New Zealand.

§ The determined specimen in USNM is wrongly labelled a paratype.

¶ The seven specimens in USNM determined by Malloch have been redetermined by Steyskal as typical *P. flavitarsis* (Macq.).

irregularis Mall. (*Giraffomyia*): M129(97–98) ..	BM (NH)			
irregularis Mall. (*Psilopa*): M106(314–315) ..	Bishop M		1 BM (NH)	
irregularis Mall. (*Uclesiella*): M119(167–168) ..			1 USNM	1 Malloch USNM
irrorata Tonn. & Mall. (*Hyadina*): M34(16–17) ..	C'bury M		1 USNM	
irrorata Tonn. & Mall. (*Neolimnia*): M48(167–168)	Cawthron		1 USNM	
isolata Mall. (*Helina*): M60(398)	Amsterdam			
isolata Mall. (*Lispa*): M58(153)	BM (NH)		11 BM (NH)	
isolata Mall. (*Plethochaetigera*): M119(193–194) ..	C'bury M		1 USNM	
isolata Mall. (*Rivellia*): M70(492)	USNM	USNM		
jarvisi Tryon (*Rioxa*): M124(435)				
kaavae Mall. (*Rosenwaldia*): M112(195–196) ..	Bishop M			2 Malloch USNM
kaiteriensis (Miller) (*Hilarempis*): M83(427)				
kerteszi de Meij. (*Antineura*): M121(104) ..				1 Malloch SPHTM
kerteszi Hend. (*Cleitamoides*): M121(107)				
kirki Froggatt (*Dacus*): M81(256)				
knabi Parker (*Sarcophaga*): M75(482–483) ..				1 Malloch USNM
kochi de Meij. (*Laglaisia*): M121(112)				
kumaraensis Miller (*Macquartia*): M97(436); M97(454)				
kumaraensis (Miller) (*Peremptor*): M97(454) ..				8 Malloch USNM, in part originally determined as *vittata* Curran
lacteipennis Lamb (*Hecamede*): M111(12)				
lacteipennis (Loew) (*Milichiella*): M18(336); M78(77); M106(326); M111(3)				1 Malloch SPHTM
lacteipennis Mall. (*Phytomyza*): M110(342) ..	USNM			
lacteiventris Mall. (*Milichiella*): M78(77–78) ..	SPHTM			
lacuans Miller (*Chorisops*): M45(364)				
lacustris Mall. (*Dichaetomyia*): M60(404)	Amsterdam			
lacustris Tonn. & Mall. (*Parahyadina*): M34(17)	C'bury M		1 USNM	2 Wirth USNM
lacta Wied. (*Atherigona*): M58(158)				
laeta Walk. (*Lamprogaster*) (*Chromatomyia*): M121(145)				
laeta Guér. (*Lamprogaster*): M57(516)				4 Malloch USNM
lagarosia Hend. (*Pseudepicausta*): M121(118)				
lamellata Mall. (*Zealandotachina*): M119(232) ..	Cawthron			
lancifer Mall. (*Hyalomyia*): M72(309)	C'bury M	USNM		
lancifer Mall. (*Sapromyza*): M30(41–42)	SPHTM			
lantanae Froggatt (*Agromyza*): M38(426) ..				10 Malloch USNM
laquei (Hutt.) (*Allophylopsis*): M39(97)				
lasiophthalma Mall. (*Froggattimyia*): M104(6–7) ..	CSIRO			
lasiophthalma Mall. (*Pilimyia*): M68(329–330) ..	SPHTM			
lasiophthalma Mall. (*Tethina*): M111(17)	Bishop M	Bishop M	3 Bishop M; 3 USNM	
lata Mall. (*Actia*): M68(307)	SPHTM			
lateralis Mall. (*Procissio*): M119(204–205).. ..			1 USNM	
lateralis Kert. (*Ptilona*): M124(464)				
latericia Hend. (*Pterogenia*): M57(513); M121(126)				
†*laticeps* Mall. (*Protomiltogramma*): M69(445–446)	SPHTM	USNM		
laticornis Mall. (*Avibrissina*): M119(179)	Cawthron			
laticornis Mall. (*Neotachina*): M119(243)	Cawthron		1 USNM	1 Malloch USNM
laticosta (Thoms.) (*Homoneura*): M59(80); M61(413); M133(141)				
latifascia (Walk.) (*Cleitamoides*): M121(107)				
latifrons Mall. (*Eucompsomyia*): M36(326)				
latifrons Mall. (*Incurviseta*): M38(404–405) ..	SPHTM			
latifrons Mall. (*Platytachina*): M119(211–212) ..	USNM	USNM		
latifrons Mall. (*Scaptomyza*): M96(221–222); M112(194)	Bishop M		1 Bishop M; 2 USNM	
latifrons Mall. (*Zealandotachina*): M119(233) ..	Cawthron			
latimana Mall. (*Cryptochaetum*): M38(422) ..	SPHTM			
latimana Mall. (*Microtropeza*): M55(287); M67(100)	Aust. M			4 Paramonov SPHTM; 1 Malloch Aust. M; 4 Malloch USNM
‡*latimana* Mall. (*Spilogona*): M83(380)	USNM			
latipes Meig. (*Hypaspistomyia*): M111(3)				
latipes Meig. (*Piophila*): M25(316); M80(292) ..				2 Malloch SPHTM; 1 Malloch USNM
§*latitarsis* Mall. (*Botanobia*): M134(58)	CSIRO	USNM		
latitarsis Mall. (*Coenosia*): M22(332)	SPHTM			1 Ferguson SPHTM
lativentris Mall. (*Hyalomyia*): M54(110–111); M67(97)	USNM			
latividens Walk. (*Achias*): M121(137)				1 Malloch USNM; 1 Malloch Aust. M
lativittata Mall. (*Drosophila*): M12(618)	Aust. M	USNM	1 USNM	2 Malloch USNM
lauta Wied. (*Orthellia*): M15(513)				1 Bezzi SPHTM; 5 Malloch USNM
lavata Hend. (*Rivellia*): M73(221)				
leai Mall. (*Helina*): M30(49)	SPHTM			
leonina (Fabr.) (*Amenia*): M37(344); M55(286); M67(101); M99(74–75)				26 Paramonov, 1 Malloch SPHTM; 5 Malloch USNM
leontodontis de Geer (*Tephritis*): M124(462)				
leopoldi Mall. (*Euphumosia*): M107(13–14) ..	Bruxelles			

† The USNM specimen listed as allotype was labelled paratype by Malloch.

‡ The collector of the holotype is J. W. Campbell.

§ Allotype (headless as noted in description) (labelled "paratype" by Malloch) in USNM.

lepida Curran (*Euprosopia*): M129(79–81) ..				1 Malloch USNM; 1 Malloch Aust. M
lepida Walk. (*Lamprogaster*): M45(349); M57(516)				1 Malloch SPHTM; 5 Malloch USNM
lepida Guér. (*Rutilia*): M44(332); M44(335); M55(301); M114(16–17)				8 Malloch USNM; 1 Malloch Aust. M
lepidofera Mall. (*Hyalomyia*): M54(111–112); M67(97)	USNM			Associated ♀, 7 Malloch USNM; 2 Malloch SPHTM
lepidofera Stein (*Pygophora*): M58(161)				
leucosticta Bez. (*Calliphora*): M73(234)				5 Malloch USNM; 2 Malloch SPHTM
leucosticta Sch. (*Rutilia*): M44(331); M44(334–335); M55(296); M67(107)				1 Malloch Aust. M
leucosticta var. *fuscisquama* Mall. (*Rutilia*): M67(107)	CSIRO		1 USNM; 2 CSIRO	
leucosticta (Bez.) (*Trypaneoides*): M66(203–204)				
leucoteles Walk. (*Xanruta*): M124(440)				
leucozona (Fall.) (*Thelaïria*): M67(110)				2 Malloch SPHTM; 4 Malloch USNM
leveri Mall. (*Homoneura*): M133(138–139) ..	BM (NH)		4 BM (NH)	
levis Hutt. (*Asteia*): M71(231–232)				
lichwardti Mall. (*Sapromyza*): M69(434)	DEI			
ligurriens Wied. (*Hemipyrellia*)				2 Malloch SPHTM
limbata Austen (*Stomoxys*): M58(175)				
limpida (Hutt.) (*Millerina*): M26(139–140); M72(293)				2 Malloch USNM
lineata Tonn. & Mall. (*Allophylopsis*): M39(92) ..	Cawthron			
lineata Mall. (*Diplotoxa*): M83(417)	USNM	USNM	3 USNM	
lineata de Meij. (*Paratimia*): M106(313); M111(11)				
lineolatus Wied. (*Telostylinus*): M110(343)				
littoralis (Hutt.) (*Chaetocoelopa*): M101(350)				
littorea (Hutt.) (*Macrocanace*) (*Milichia*): M34(5)				
lituratа (Walk.) (*Cleitamoides*): M121(107)				
lobata Stein (*Pygophora*): M10(382)				1 Malloch SPHTM; 4 Malloch USNM
lonchifera Hend. (*Scholastes*): M63(99); M73(222); M96(205–206); M121(129)				3 Malloch USNM
longicollis Walk. (*Angitula*): M122(170, 179) ..				2 Malloch SPHTM
longicornis Hend. (*Cerataulina*): M41(102)				
longicornis Guér. (*Dacus*): M81(259)				
longicornis Mall. (*Neoaanenia*): M67(103)	CSIRO			
longicornis Macq. (*Passeromyia*): M23(46)				1 Malloch SPHTM
**longicornis* Mall. (*Plagiomyia*): M119(171) ..	Cawthron			Okarahia & Mt Arthur specimens USNM
longicornis Ferg. (*Spaniopsis*): M79(275)				6 Malloch USNM
longipalpis (Hend.) (*Neotoxura*): M53(23–24) ..				1 Malloch SPHTM
longipalpis Hend. (*Toxura*): M53(7)				
longipennis Mall. (*Trypanea*): M83(398–400) ..	C'bury M		4 USNM	1 F. A. Perkins BM (NH)
longipes Mall. (*Plagiomyia*): M119(170)	Cawthron			1 Malloch SPHTM
longipes (Macq.) (*Rhyncodexia*): M67(119) ..				6 Malloch USNM; 2 Malloch SPHTM
longirostris Mall. (*Avibrissia*): M97(437)	Cawthron			
longividens Walk. (*Achias*): M121(137)				
loranthi (Froggatt) (*Ceratitella*): M124(452–453) ..	SPHTM			
lucifera Dahl. (*Puliciphora*): M110(339)				
lupina (Sved.) (*Hystricina*): M97(433–434) ..				2 Malloch USNM
lutea Mall. (*Cristobalia*): M124(448); M126(265)..	BM (NH)			
lutea Mall. (*Pachylophus*): M24(95); M38(428) ..	SPHTM			3 Malloch Sabrosky Coll
luteicornis Mall. (*Oscinosoma*): M78(64–65); M134(59)	SPHTM		1 USNM; 1 SPHTM	
luteipennis Bez. (*Tapeigaster*): M69(436)				
luteohirta Mall. (*Dichaetomyia*): M22(326).. ..	SPHTM	SPHTM	1 USNM	1 Malloch SPHTM
luteohirta Mall. (*Oscinosoma*): M78(65)	SPHTM		1 CSIRO	
luteola Mall. (*Dacus*): M81(262)	BM (NH)			
mackerrasi Mall. (*Conioscinella*): M128(284) ..	SPHTM	SPHTM	3 SPHTM; 2 USNM	
macleayi Mall. (*Calliphora*): M36(310–311) ..	SPHTM		2 USNM (damaged)	1 D. Aubertin BM (NH); 1 Malloch USNM
macrocephala Hend. (*Lamprogaster*): M121(145)				
macronycha Mall. (*Maorina*): M71(239)	C'bury M			
macrotegularia Mall. (*Euprosopia*): M45(345); M57(512); M69(430)	USNM	USNM	3 USNM	2 Malloch USNM; 1 Malloch SPHTM
macularis (Walk.) (*Paramenia*): M44(330); M46(614)				2 Engel, 5 Paramonov SPHTM; 1 Malloch Aust. M; 1 Malloch USNM (as *P. semiauriceps*)
macularis Wied. (*Pygophora*): M60(395)				
maculifer Mall. (*Chloromerus*): M38(432)	CSIRO			
maculifrons (Macq.) (*Incurviseta*): M25(324); M38(403–404)				
maculifrons (Macq.) (*Homoneura*): M24(83)				
maculipennis Mall. (*Berisina*): M45(365)	C'bury M		2 USNM	10 Aldrich USNM
maculipennis Hend. (*Duomyia*): M57(511) ..				1 Malloch USNM
maculipennis Bez. (*Epicerella*): M53(14)	SPHTM			2 Bezzi SPHTM
maculipennis Guér. (*Euprosopia*): M45(346); M46(612); M69(430)				

* The specimens in USNM were labelled paratypes by Malloch.

maculipennis Mall. (*Homalocnemis*): M97(458) ..	USNM	USNM	
maculipennis Mall. (*Huttonomyia*): M31(552) ..	SPHTM		
maculipennis Macq. (*Lamprogaster*): M121(143)			
**maculipennis* Mall. (*Limnellia*): M25(332) ..	SPHTM		
maculipennis Macq. (*Toxura*): M53(8); M53(24)			1 Malloch USNM
maculithorax Mall. (*Sapromyza*): M30(43–44); M35(12)	SPHTM		1 USNM	2 Malloch SPHTM; 2 Malloch USNM
†*maculiventris* Mall. (*Amenia*): M55(323)				
magnicornis Mall. (*Pseudoleucopis*): M24(93); M70(490)	SPHTM			
magnicornis Mall. (*Sapromyza*): M30(39) ..	SPHTM			
‡*magnifica* Hend. (*Brea*): M121(125)				1 Malloch SPHTM
magnifica Mall. (*Sapromyza*): M30(40)	SPHTM			1 Tonnoir USNM
magnus Beck. (*Prionoscelus*): M114(25–26)				
major Mall. (*Batrachomyia*): M38(410–441); M128(264)	CSIRO		1 USNM; 1 CSIRO	
major Mall. (*Delta*) (*Deltomyza*): M68(334–335) ..	SPHTM			
major Mall. (*Marquesia*): M96(223)	Bishop M			
major Mall. (*Melanina*): M38(413); M109(89) ..	SPHTM	CSIRO		1 Malloch SPHTM; 2 Malloch USNM
major Mall. (*Platytachina*): M119(213–215) ..	Cawthron		2 USNM	
malaita Curran (*Maquilingia*): M133(144)				
malaita Curran (*Platensina*): M124(458); M126(277)				
malayana Town. (*Prosena*): M85(132)				2 Curran SPHTM
marginalis Mall. (*Elassogaster*): M129(68–70) ..	BM (NH)	BM (NH)	7 BM (NH)	
marginata (Fall.) (*Sphenella*): M124(459–460) ..				1 Malloch, 1 Taylor SPHTM; 2 Malloch USNM
marginata Mall. (*Tephritis*): M83(394–395) ..	C'bury M		1 USNM	
marginifrons Bez. (*Tapeigaster*): M68(436); M86(217)			1 SPHTM	1 Malloch USNM
mariae Mall. (*Sapromyza*): M35(11)	SPHTM		2 USNM	
marina Mall. (*Rivellia*): M131(19)	BM (NH)		1 BM (NH)	
maritima Haliday (*Fucellia*): M25(339–340) ..				1 Malloch SPHTM
marquesana Mall. (*Asteia*): M112(190–191) ..	Bishop M			
marquesana Mall. (*Melanagromyza*): M111(19) ..	Bishop M			2 Malloch USNM
marquesana Mall. (*Mosillus*): M111(13–14) ..	Bishop M			
mastersi Skuse (*Ceroplatus*): M46(600)				
matema Curran (*Maquilingia*): M133(144)				
media Mall. (*Paroxyna*): M118(116)	Bishop M	USNM		
megacephala (Fabr.) (*Chrysomyia*): M33(205); M36(328); M72(315); M73(233); M107(21)				2 Malloch SPHTM
megalotis Gerst. (*Elaphomyia*): M122(180)				
megaphthalma Mall. (*Dichaetomyia*): M22(325–326)	USNM			1 Malloch SPHTM
melanaspis Wied. (*Pteria*): M46(602–603)				
melanogaster Meig. (*Drosophila*): M12(617).. ..				8 Malloch SPHTM; 8 Malloch USNM
melanogaster (Thoms.) (*Steganopsis*): M24(81–82); M133(132)				1 Tonnoir USNM
melanotus Coq. (*Dacus*): M81(255)				
melbournensis (Mall.) (*Astiosoma*): M76(322)				
§*melbournensis* Mall. (*Sigaloessa*): M38(445); M76(322)	SPHTM			
meleagris Sch. (*Tephritis*): M124(460)				
mellea Mall. (*Dichaetomyia*): M60(406)	Amsterdam			
mesolissa Bez. (*Limnophora*): M58(165); M65(330–331)				
mesopleuralis (Beck.) (*Lioscinella*): M134(53) ..				12 Malloch USNM and Sabrosky Coll.
mesopleuralis Mall. (*Pseudospheniscus*): M124(450); M127(242)	BM (NH)			
mestor Walk. (*Tachina*): M119(211–212)				
metallescens de Meij. (*Drosophila*) (*Lissocephala*): M106(289)				
metallica Mall. (*Calliphora*): M36(317–318)				
metallica (Hutt.) (*Psilopa*): M34(12)				
metatarsata Stein (*Lispa*): M58(155)				
micans Hutt. (*Anabarrhynchus*): M90(241)				
micans (Hutt.) (*Ectinorrhynchus*): M90(241)				
micans Mall. (*Helina*): M9(142); M23(42).. ..	BM (NH)			1 Malloch SPHTM
micans Mall. (*Rutilia*): M55(299); M67(108) ..	Aust. M		3 Aust. M	2 Malloch USNM
microcephalus Hend. (*Achias*): M121(137)				
microcera Mall. (*Fergusonina*): M18(338); M24(92); M86(213, 215)	CSIRO			1 Malloch USNM
micropalpus Mall. (*Rutilia*): M55(298); M114(16)..	Aust. M		1 Aust. M	1 Malloch, 2 Paramonov SPHTM; 2 D. J. Clark BM (NH); 2 Malloch USNM
micropalpis Mall. (*Stomatomyia*): M68(321) ..	SPHTM			
micropogon Big. (*Chrysomyia*): M36(328)				2 Malloch, 1 Patton, 2 Hill SPHTM; 8 Malloch USNM
microps Hend. (*Toxura*): M53(7)				
miliacea Hend. (*Epicerella*): M53(13); M53(26)				2 Bezzi SPHTM
miliaria Hend. (*Euprosopia*): M45(346); M57(512); M121(148–149); M129(78)				1 Malloch USNM
millepuncta Mall. (*Paralimna*): M25(325–326) ..	SPHTM		1 USNM	1 Malloch, 3 Ferguson SPHTM
milleri Tonn. & Mall. (*Eulimnia*): M48(172–173) ..	Cawthron		1 USNM	

* Type is dated 25.9.21 not 29.5.21 as stated in the description.
† Quoted as *Amenia maculiventris* mihi, this species is mentioned but no indication of description is given.
‡ One specimen in SPHTM determined by Malloch appears to be *B. contraria* Walk.
§ Type bears the name *S. melbournii*.

milleri Mall. (*Procissio*) : M119(201–202)	Cawthron		2 USNM	
mima Town. (*Zosteromeigenia*) : M55(315)				
minor Mall. (*Asteia*) : M112(192)	Bishop M		2 USNM	
minor Mall. (*Calliphora*) : M36(314–315)				4 Malloch USNM
minor Mall. (*Diplochorda*) : M122(178–179) ..	SPHTM		1 USNM	
minor Bez. (*Epicerella*) : M53(15)	SPHTM			
**minor* Mall. (*Erythronychia*) : M97(444–445) ..	C'bury M			
minor Hend. (*Euphranta*) : M124(443)				
minor Mall. (*Euprosopia*) : M129(82–84)	BM (NH)	BM (NH)	1 USNM ; 5 BM (NH)	
minor Mall. (*Genotrichia*) : M119(165)	C'bury M			
minor Mall. (*Stilbomyia*) : M67(102–103) ..	CSIRO			
minthaphila Collin (*Hilarempis*) : M83(427) ..				3 Malloch USNM
minuta Tonn. & Mall. (*Allophylopsis*) : M39(95) ..	Cawthron			
minuta Mall. (*Euprosopia*) : M121(148)	BM (NH)		1 BM (NH)	
minuta Mall. (*Leucophenga*) : M35(2)	SPHTM			
minuta Mall. (*Melinda*) : M44(328–329) ; M114(22–23)	USNM	USNM		1 Malloch SPHTM ; 2 Malloch USNM
minuta Tonn. & Mall. (*Neolimnia*) : M48(170) ..	Cawthron			
†*minuta* Tonn. & Mall. (*Poecilohetaerella*) : M34(26)	C'bury M		1 USNM	
minuta Mall. (*Pygophora*) : M5(239) ; M10(383) ; M58(161) ; M60(396)	BM (NH)			
minutula Mall. (*Chlorops*) : M74(250)	Bishop M			
minutula Mall. (*Lioscinella*) : M134(54–55) ..	SPHTM			
mirabilis Guér. (*Formosia*) : M37(350) ; M55(309) ..				
‡*mirabilis* Lamb (*Pemphigonotus*) : M116(354) ..				1 specimen from type series, 1 compared cotype SPHTM
mixta Mall. (*Austrodexia*) : M67(126)	SPHTM			
m-nigrum Zett. (*Desmometopa*) : M106(327)				
modesta Mall. (*Lasiocalpytrina*) : M67(122) ..	SPHTM		1 USNM	
modica Hutt. (*Procissio*) : M119(205)				4 Malloch USNM (as *Peremptor modica*)
moneta Gerst. (*Formosia*) : M55(309)				
monophlebi Skuse (*Cryptochaetum*) : M38(422–423)				1 Malloch SPHTM
monstruosa (Hutt.) (*Chaetocoelopa*) : M101(350)				
monstruosa Wulp (*Monocera*) : M133(135) ..				
§*montana* Mall. (*Acucera*) : M68(328)		CSIRO (damaged)	1 CSIRO ; 2 USNM	
montana Hutt. (*Procissio*) : M119(204)				
montanum Mall. (*Melanum*) : M116(352–353) ..	SPHTM			
monticola Mall. (*Chloropisca*) : M38(430) ; M116(354)				
monticola Mall. (*Engycera*) : M111(181–182) ..	C'bury M		1 USNM	
monticola Mall. (*Philygriola*) : M111(15–16) ..	Bishop M			
montium de Meij. (*Drosophila*) : M106(301)				
multiloides (Walk.) (*Pseudepicausta*) : M121(119)				
multipunctata Mall. (*Epicerella*) : M53(27–28) ..	USNM		1 USNM	
multipunctata Mall. (*Hexacinia*) : M124(438–439) ..	SPHTM		2 USNM (1 fragmentary)	1 F. van Emden BM (NH)
¶*multisulcata* Mall. (*Chlorops*) : M83(420) ..	C'bury M		3 C'bury M; 19 USNM	
multisulcatum Mall. (*Melanum*) : M116(352) ..	SPHTM			
‖*mumfordi* Mall. (*Calliphora*) : M92(15)	Bishop M			
mumfordi Mall. (*Scaptomyza*) : M111(22–23) ; M112(194)	Bishop M		51 Bishop M; 20 USNM	
musae Frogg. (*Trypeta*) : M124(435)				
mutabilis Collin (*Dipsomyia*) : M83(428)				
***mycetophaga* Mall. (*Drosophila*) : M19(351) ..	Aust. M	USNM		
myrmecophila Knab & Mall. (*Leptocera*) (*Limosina*) : M1(236–237) ; M44(326)	USNM			
myrmex Ost.-Sack. (*Diplochorda*) : M122(176) ..				2 Malloch SPHTM ; 1 Malloch USNM
narranderae Mall. (*Limnophora*) : M25(340) ..	SPHTM			
nasalis Duda (*Dasydrosophila*) : M106(291)				
nasuta Lamb (*Drosophila*) (*Spinulophila*) : M106(311) ; M113(20–21) ; M112(193)				7 Malloch USNM
nasuta Mall. (*Prochaetops*) : M112(184–185) ..	Bishop M		3 USNM	
nebulifera Mall. (*Platyina*) : M38(436)	CSIRO		1 USNM	
nelsoni Mall. (*Idiohelina*) : M62(263–264) ; M72(304)	SPHTM		2 SPHTM ; 2 USNM ; 3 BM (NH)	1 Malloch USNM
††*nelsoni* Mall. (*Limnohelina*) : M72(303) ..	C'bury M	C'bury M	1 C'bury M ; 2 USNM	
nelsoni Tonn. & Mall. (*Scatella*) : M34(11)	C'bury M			1 Tonnoir USNM
neodaphne var. *gamma* Mall. (*Trypanea*) : M124(462)	BM (NH)			
‡‡*neozealandica* Mall. (*Oscinosoma*) : M83(414) ..	C'bury M		7 C'bury M ; 8 USNM	
neozealandica Tonn. & Mall. (*Parydra*) : M34(9) ..	C'bury M			
neozealandica Tonn. & Mall. (*Sapromyza*) : M34(22–23)	C'bury M			2 F. van Emden BM (NH)

* USNM has the Queenstown specimen, referred to by Malloch. He labelled it a paratype but it does not seem that it can be regarded as such, since in publication it was questionably referred to *E. minor*.

† The paratype in USNM is 1922, not 1921.

‡ See also J. R. Malloch, 1931, *Ann. Mag. Nat. Hist.*, Ser. 10, v. 7 : 473–75.

§ As the type of this species is also the type specimen of the genus, it would appear that this was retained by Malloch and subsequently lost.

¶ The whole type series has been seen but no allotype was specifically designated by Malloch.

‖ The data on the type reads November 13, 4050 ft., not September 13, 4000 ft.

** The allotype actually bears a paratype label.

†† There are slight errors in the published data : Reefton, Jan. 13 (not Jan. 1), and Dun Mt., Jan. 5–7 (not Jan. 6–7).

‡‡ No specimen in the type series was designated allotype.

neozealandica Mall. (*Teratomyza*): M102(113–114)..	Cawthron		1 USNM (headless)	
neozealandicum Mall. (*Melanum*): M83(418–419) ..	C'bury M	C'bury M	1 USNM	
**neozelandicus* Mall. (*Protoborborus*): M102(262) ..	BM (NH)	C'bury M	1 USNM	
nicholsoni Mall. (*Drosophila*): M35(4–5)	SPHTM		2 USNM	
nicholsoni Mall. (*Froggattimyia*): M104(5) ..	SPHTM			
nicholsoni Mall. (*Prosenina*): M67(116–117) ..	CSIRO	SPHTM	3 CSIRO; 2 USNM	
nicobarensis (Sch.) (*Pseudoformosina*): M116(355–356); M134(64)				
niger Mall. (*Apocephalus*): M109(95)	SPHTM			
nigra de Meij. (*Cheesmanomyia*) (*Riacza*): M124(420)				
nigra Ender. (*Hammatopelma*): M122(179)				
nigra Wied. (*Ophyra*): M13(666); M58(169); M60(399); M95(197)				1 Malloch USNM; 1 Malloch SPHTM
nigrescens Stein (*Helina*): M13(670–671); M23(41)				4 Malloch USNM
nigribarba Aldr. (*Metallea*): M36(331)				1 Malloch SPHTM
nigricauda Mall. (*Homoneura*): M66(209–210) ..	Bishop M		3 BM (NH)	
nigriceps Mall. (*Chaetomosillus*): M105(1) ..	DEI			
nigriceps Macq. (*Orthellia*): M15(514)				10 Malloch USNM; 2 Malloch SPHTM
nigriceps Mall. (*Rutilia*): M55(306); M67(109) ..	Aust. M		3 Aust. M	6 Malloch USNM
nigricornis Ender. (*Actina*): M45(364)				
nigricornis Thoms. (*Prohippelates*): M96(216)				
nigricornis flavus Thoms. (*Prohippelates*): M134(64)				1 Malloch SPHTM
nigricornis (Macq.) (*Sapromyza*): M45(359)				
nigricornis Mall. (*Semisuturia*): M37(341) ..	BM (NH)			
nigricosta Mall. (*Cylindromyia*): M68(312–314) ..	SPHTM (Wings only)			
†*nigricosta* Mall. (*Duomyia*): M57(511)	DEI		2 USNM	
nigridorsata Mall. (*Hippelates*) (*Cadrema*): M38(439); M128(277)	CSIRO			
nigridorsata Mall. (*Limnophora*): M65(333); M95(199)	USNM			
nigridorsum Mall. (*Aphaniosoma*): M24(94) ..	SPHTM		8 SPHTM; 3 USNM	
nigrifacies Mall. (*Achiosoma*): M121(131) ..	Aust. M			
nigrifacies Mall. (*Euphumosia*): M107(15–16) ..	Bruxelles			
‡*nigrifemorata* Mall. (*Medinella*): M119(235–236)..	C'bury M			
nigrifemorata Mall. (*Zealandotachina*): M119(227)..	C'bury M		9 USNM	2 Malloch USNM
§*nigrifemur* Mall. (*Chloromerus*): M38(431–432) ..	CSIRO	CSIRO	1 USNM; 1 CSIRO	
nigrifemur Mall. (*Millerina*): M26(141); M72(293)	USNM			
nigrifrons Mall. (*Drosophila*): M106(304–305) ..	Bishop M	BM (NH)	3 BM (NH)	
nigrifrons (Kert.) (*Homoneura*): M132(22)				
nigrifrons Mall. (*Xanthocanace*): M18(334) ..	SPHTM			
nigrihirta Mall. (*Hyalomyia*): M54(112); M67(97)..	USNM		4 SPHTM; 7 USNM	4 Malloch SPHTM; 3 Malloch USNM
¶*nigrihirta* Mall. (*Lasiocalypter*): M67(119–120) ..	SPHTM		2 USNM	1 Curran SPHTM
nigrihirta Mall. (*Macquartia*): M119(222–223) ..	Cawthron		1 USNM	
nigrihirta Mall. (*Rutilia*): M110(349–350) ..	BM (NH)			
||*nigrimana* Mall. (*Botanobia*): M134(59)	CSIRO			
nigrimana Mall. (*Paralauxania*): M38(411–412) ..	CSIRO			
nigrimana Mall. (*Xenolispa*): M12(611)	Aust. M (headless)			2 Malloch USNM
nigriorbitalis Mall. (*Limnophora*): M17(144) ..	SPHTM			2 Malloch USNM
nigripennis de Meij. (*Acanthoneura*): M124(429–430)				
nigripennis Rend. (*Trypanoceuta*): M124(428, 430)				
nigripes Stein (*Atherigona*): M14(192)				
nigripes Mall. (*Dichaetomyia*): M60(404)	Amsterdam			
nigripes Mall. (*Elassogaster*): M129(70)	BM (NH)		1 BM (NH)	
***nigripes* Mall. (*Exechopalpus*): M67(132) ..	SPHTM			
nigripes Mall. (*Limnohelina*): M72(301)	C'bury M	USNM	1 C'bury M	
nigripes Mall. (*Milichiella*): M78(77)	SPHTM		1 USNM	
nigripes Mall. (*Pollenia*): M72(320)	USNM			
nigripes Curran (*Prosena*): M67(115); M85(130)..				2 Malloch SPHTM; 1 Malloch USNM
nigripila Duda (*Lasiopleura*): M114(24–25); M128(272)				1 Malloch SPHTM; 1 Malloch Sabrosky Coll.
nigriseta Bez. (*Prochaetops*): M91(3)				
nigriseta (Mall.) (*Rhicnoessa*): M111(18)				
††*nigriseta* Mall. (*Tethina*): M18(337); M109(92)..	SPHTM			1 Malloch SPHTM; 1 Malloch USNM; 1 Malloch BM (NH)
nigrisquama Mall. (*Hyalomyia*): M54(110); M67(95)	Aust. M			
nigrisquama Mall. (*Pollenia*): M72(319–320) ..	USNM			
nigrita Mall. (*Dohrniphora*): M25(334)	SPHTM			
nigrita Mall. (*Pollenia*): M114(22)	SPHTM			
nigritalla Mall. (*Lonchaea*): M74(241)	BM (NH)	BM (NH)		
nigrithorax Mall. (*Anomoea*): M124(449)	SPHTM			
nigrithorax Mall. (*Mycodrosophila*): M106(284–285)	BM (NH)		? 3 BM (NH)	

* The type is a ♂, not a ♀ as stated. The paratype is a ♂ (as stated) and the allotype a ♀.

† The two paratypes in USNM were labelled as such by Malloch but no paratypes were specifically mentioned in the original description.

‡ The aberrant specimen from Arthur's P. is in USNM, labelled paratype by Malloch but is not so from the publication.

§ USNM has a specimen labelled paratype by Malloch *ex* Cradle Valley but it is 16 Jan. 1923, not 16 Dec. 1923.

¶ Locality of type specimen is Kosciusko, 11 February 1924 (Nicholson), and not Barrington Tops as stated in the description.

|| The CSIRO type comprises two specimens on one pin.

** Type specimen bears the name *E. atripes*.

†† The identified specimen in USNM is from Sydney, Feb. 1925, and is labelled "paratype". The species was described from one specimen from Woolgoolga, published in Oct. 1924, five months before this was collected. The Sydney specimen, which cannot be a paratype, is one of those recorded in M109(92).

nigrithorax Mall. (*Taeniomyia*): M60(390).. ..	Amsterdam			
nigrithorax Mall. (*Trypanocentra*): M124(428–429)	SPHTM			
nigritula Mall. (*Actia*): M68(309)	SPHTM		2 USNM; 1 SPHTM	2 Campbell SPHTM; 13 F. van Emden BM (NH)
nigriventris Mall. (*Acanthoneura*): M124(432–433)..	SPHTM			
nigriventris Mall. (*Vespivora*): M68(347)		CSIRO	1 CSIRO; 1 USNM (headless)	
nigroannulata Mall. (*Botanobia*): M25(338–339); M134(57)	SPHTM		1 SPHTM	
nigroannulata Mall. (*Oscinosoma*): M78(61); M134(48)	CSIRO			
nigroapicata Mall. (*Homoneura*): M61(412) ..	Amsterdam			
nigrocaerulea Mall. (*Chlorotachina*): M55(324–325)..	Aust. M			4 D. J. Clark BM (NH)
nigrohalterata Mall. (*Chloropsina*): M18(333) ..	SPHTM			1 Malloch Sabrosky Coll.
nigrohalterata Mall. (*Helina*): M23(41); M23(43)..	SPHTM			
nigrohirta (Mall.) (*Botanobia*): M78(65); M134(61)				
**nigrohirta* Mall. (*Oscinosoma*): M78(65); M134(61)	SPHTM	SPHTM	SPHTM	
nigromaculata Mall. (*Amenia*): M55(286); M67(102); M99(76)	CSIRO	CSIRO		
nigropolita Mall. (*Asetulia*): M119(188–189) ..	C'bury M		3 USNM	
nigropolita Mall. (*Limnophora*): M95(198–199) ..	Bishop M		1 USNM	
†*nigropolita* Mall. (*Lioscinella*): M134(47) ..	SPHTM	SPHTM	2 USNM	
nigroscutellata Beck. (*Assuania*): M78(69)				
nigroscutellata Mall. (*Dohrniphora*): M25(334) ..	SPHTM			
nigroviolacea (Mall.) (*Lioscinella*): M78(63); M134(46)				
nigrovittata Mall. (*Drosophila*): M19(352) ..	SPHTM			
nitens Walk. (*Rutilia*): M44(333); M44(335)				
nitens Mall. (*Stilbomyella*): M108(75–76)	SPHTM			
nitidifrons Tonn. & Mall. (*Scatella*): M34(11–12) ..	C'bury M		1 USNM	10 F. van Emden BM (NH); 2 Wirth USNM
nitidifrons var. *subvittata* Tonn. & Mall. (*Scatella*): M34(12)	Presumably C'bury M			
nitidithorax Macq. (*Actina*): M45(364)				
nitidithorax Mall. (*Drosophila*): M35(5)	SPHTM		1 USNM	
‡*nitidithorax* Mall. (*Scatella*): M25(330–331); M34(11)	SPHTM			1 Malloch USNM
nitidiventris Tonn. & Mall. (*Neolimnia*): M48(170)..	Cawthron			
nitidiventris Mall. (*Pygophora*): M60(396) ..	Amsterdam			
nitidiventris Mall. (*Semisuturia*): M37(341) ..	BM (NH)			
nitidula Mall. (*Leiomyza*): M18(338)	Aust. M			1 Malloch SPHTM
nitidula Mall. (*Phytomyza*): M110(342)	USNM			
niveifasciata Mall. (*Leucophenga*): M12(614–615)..	Aust. M		2 USNM	5 A. Collart BM (NH)
nivistriga Walk. (*Rioxa* ?) (*Helomyza*): M124(464)				
noctilux (Walk.) (*Pseudoformosina*): M116(355–356); M134(64)				
norma Mall. (*Actia*): M54(116); M68(307).. ..	USNM			
normalis (Curran) (*Hyalomyia*): M67(95)				
normalis Mall. (*Miltogramma*): M69(443)			1 USNM	
nosocomiorum Dol. (*Lucilia*): M36(322); M92(16)				
notabilis Macq. (*Laphria*): M46(609)				
notativentris Mall. (*Homoneura*): M133(142) ..	BM (NH)			
nouhuysi de Meij. (*Brea*): M121(124)				
novae-zealandiae Tonn. & Mall. (*Ephydra*): M34(8–9)	C'bury M		2 USNM	1 Aldrich USNM
novoguinensis Duda (*Drosophila*): M106(277) ..				1 Malloch SPHTM; 1 Malloch USNM
nubecula Hend. (*Pterogenia*): M57(513); M121(126)				
nubeculosa Mall. (*Arnomyia*): M63(97–98) ..	USNM	USNM	1 BM (NH); 2 USNM	1 Zimmerman BM (NH)
nubeculosa Mall. (*Idiohelina*): M5(238–239); M62(262–263); M72(304)	USNM		1 USNM	
nubeculosa Tonn. & Mall. (*Scatella*): M34(10) ..	C'bury M			1 Tonnoir USNM
nubila Mall. (*Homoneura*): M65(322–323) ..	USNM			
nubilipalpis Mall. (*Chlorops*): M78(72)				
nubilipalpis (Mall.) (*Oscinis*): M78(72); M116(342)				
§*nuda* Mall. (*Fenwickia*): M72(338–339)	C'bury M	USNM		
nuda Mall. (*Samoaia*): M106(277–278)	Bishop M			
nudarum Mall. (*Campylia*): M119(240)	C'bury M		2 USNM	
nudibasis Mall. (*Opsidiopsis*): M69(439–440)	SPHTM			
nudiseta (Beck.) (*Lasiopleura*): M12(621); M18(331); M128(274)				2 Malloch SPHTM; 1 Malloch S.A. Mus
nudiseta Beck. (*Parahippelates*): M12(621); M18(331)				2 Malloch Sabrosky Coll.
nudiseta Wulp (*Synthesiomyia*): M58(174) ..				1 Aldrich SPHTM
oahuae Mall. (*Lispocephala*): M52(87)	Bishop M			
obesa Mall. (*Zebromyia*): M55(321)	Aust. M		1 Aust. M	1 Malloch USNM
obliquus Mall. (*Dacus*): M126(238–240)	BM (NH)			
obliterata Mall. (*Anaclysta*): M12(602–603) ..	Aust. M	USNM		
obscura Tonn. & Mall. (*Allophylopsis*): M39(99)..	Cawthron			
obscura Walk. (*Duomyia*): M45(351); M57(510–511)				
obscura (Hutt.) (*Neolimnia*): M48(166)				

* Allotype and the paratype in SPHTM not recorded in the original description. Their locality labels agree with specimens mentioned in M134(61).

† Error by Malloch in recording two paratypes (now in USNM) as from "Darwin (Palmerston)". Both are clearly labelled as Palmerston North, N.Z., one "*ex* new swedes, April 1931", the other "*ex* rotted swedes, 25.3.31", both reared by W. Cottier.

‡ The identified specimen in USNM bears a paratype label. The data on the specimen is "Home, 21.5.23".

§ The USNM allotype is labelled paratype.

obscurifrons Tonn. & Mall. (*Hyadina*): M34(16) ..	C'bury M			
obscurus Mall. (*Dacus*): M81(264)	BM (NH)		3 BM (NH); 2 USNM	
obsoleta Mall. (*Drosophila*): M12(616)	Aust. M		1 USNM	1 Malloch USNM
obtusa Mall. (*Neotachina*): M119(207)	Cawthron	USNM		
obtusifrons Thoms. (*Sarcophaga*): M92(14)				
occidens Hardy (*Atherimorpha*): M79(275) ..				4 Malloch USNM
occipitalis Mall. (*Chlorops*): M83(421)	C'bury M	C'bury M	4 USNM	
occipitalis Mall. (*Sapromyza*): M30(41); M35(12)..	SPHTM			1 Malloch SPHTM; 6 Malloch USNM
ocellaris Mall. (*Oscinis*): M116(346–347) ..	SPHTM		1 SPHTM	
ocellaris Mall. (*Samoaia*): M106(271–273) ..	BM (NH)		3 BM (NH)	
ocellaris Mall. (*Sapromyza*): M38(416)	CSIRO		5 USNM; 4 CSIRO	
ocellata Tonn. & Mall. (*Neolimnia*): M48(166–167)..	Cawthron			
ochracea Sch. (*Calliphora*): M36(308); M46(613)..				2 Malloch, 1 Taylor SPHTM; 4 Malloch USNM
ochracea form *nigrithorax* Mall. (*Calliphora*): M36(308)	SPHTM			6 D. J. Clark BM (NH)
ochriventris Mall. (*Microtropeza*): M55(287–288); M67(100)	CSIRO		2 CSIRO	1 Paramonov SPHTM; 6 D. J. Clark BM (NH)
**ochroseae* Mall. (*Dacus*): M135(201)	Bishop M	Bishop M	12 Bishop M; 4 USNM	
octopunctata Mall. (*Trypaneoides*): M61(411–412)	Amsterdam			
oculata Mall. (*Cycasia*): M135(203)	Bishop M		2 Bishop M; 3 USNM	
opaca Mall. (*Delta*) (*Deltomyza*): M68(334).. ..	SPHTM		1 CSIRO	1 Malloch SPHTM
opacifrons Mall. (*Limnophora*): M17(144) ..	SPHTM			
ophion Ost.-Sack. (*Diplochorda*): M122(177)				
opposita (Walk.) (*Neactina*): M48(363)				1 Malloch USNM
optatura Walk. (*Themaroides*): M124(464)				
optica Town. (*Anaperistommyia*): M80(296)				
opulenta (Walk.) (*Stilbomyella*): M108(75)				
opulenta (Walk.) (*Stilbomyia*): M37(345); M67(103)				
orasus (Walk.) (*Cerosomyia*): M119(197)				
†*orbitalis* Mall. (*Diplotoxa*): M83(417–418) ..	C'bury M	C'bury M	1 USNM	
orbitalis Mall. (*Lispocephala*): M52(78)	Bishop M			
orbitalis Mall. (*Plagiostenopterina*): M121(114–115)	BM (NH)	BM (NH)	5 BM (NH)	
orientalis (Sch.) (*Hystricia*): M97(431–432)				
ornata Mall. (*Quadra*): M55(320–321)	Aust. M			
ornaticornis Skuse (*Plecia*): M46(604)				
ornatipennis (de Meij.) (*Homoneura*): M30(46–47); M38(419); M59(65)				1 Malloch SPHTM
ornatipennis Mall. (*Parahippelates*): M12(620) ..	S.A. Mus			
ornatipennis (Mall.) (*Lasiopleura*): M12(620); M128(270)				1 Malloch, 1 compared with type SPHTM
ornatissimus Froggatt (*Dacus*): M81(257)				
ortalioides Walk. (" *Helomyza* "): M124(464)				
orthocephala Hend. (*Cleitamia*): M121(109)				
orthoneura (Mall.) (*Limnella*): M17(144–145); M44(328)				
‡*orthoneura* Mall. (*Limnophora*): M17(144–145); M44(328)	SPHTM			3 Malloch USNM
oryzae Mall. (*Atherigona*): M28(117); M60(397) ..	USNM	USNM	18 USNM	
ostensackeni Kert. (*Cleitamia*): M121(109) ..				1 Malloch USNM
pachyprocta Nowicki (*Hystricia*): M97(431–432)				
pachyprocta (Nowicki) (*Protohystricia*): M55(342)..				1 Malloch USNM
pacifica Mall. (*Megaselia*): M110(336)	Bishop M			
pacifica Mall. (*Winthemia*): M110(359)	BM (NH)			
pagdeni Mall. (*Dacus*): M126(243–245) ..	BM (NH)			
pahangensis Mall. (*Semisuturia*): M37(341) ..	BM (NH)			
pallens Curran (*Doddiana*): M55(335); M68(342); M100(137)				1 Malloch SPHTM; 1 Malloch USNM
pallens Curran (*Rutilia*): M78(78)				
pallida Mall. (*Lispocephala*): M52(72)	Bishop M			
§*pallida* Mall. (*Stomatorhinia*): M36(333)				4 Malloch USNM; 1 Malloch SPHTM; 3 Peris BM (NH)
pallidibasis Mall. (*Lispocephala*): M52(73) ..	Bishop M			
pallidicentralis Mall. (*Agromyza*): M38(427) ..	SPHTM		1 USNM	
pallidihirta Mall. (*Austrodexia*): M67(126) ..	SPHTM		3 USNM	
pallidior Beck. (*Chloromerus*): M18(332); M116(336)				1 Malloch SPHTM; 6 Malloch USNM and Sabrosky Coll.
pallidipleura Mall. (*Lioscinella*): M134(52–53) ..	SPHTM			
pallidiseta Mall. (*Chlorops*): M78(71–72)	SPHTM			
pallidiseta Mall. (*Conioscinella*): M128(283) ..	SPHTM			
pallidiseta (Mall.) (*Czernyola*) (*Tonnoiria*): M135(209)				
pallidiseta Mall. (*Euhippelates*): M24(96–97); M38(436); M128(267)	SPHTM	USNM		1 Malloch Sabrosky Coll.
¶*pallidiseta* var. *pallipes* Mall. (*Euhippelates*): M24(97)	SPHTM	SPHTM	2 USNM	

* The actual date on the paratype series from Yigo is ix-15-1937.
† The paratype in USNM is dated Sept. 15 (not October as stated).
‡ The three determined specimens in USNM are wrongly labelled paratypes.
§ Two specimens in USNM determined by Malloch are both from Cairns, N.Q., and collected by Illingworth. As the type and paratype referred to by Malloch have not been located elsewhere, there is a possibility that these may be the two.
¶ The two paratypes in USNM are from Sydney, 15.10.24 and 29.10.24. This is not in agreement with the published data.

pallidiseta (Mall.) (*Oscinis*) : M78(71–72) ; M116(345)				
pallidiseta Mall. (*Tethina*) : M109(92–93)	SPHTM	USNM		
pallidiseta Mall. (*Tonnoiria*) : M63(99) ; M96(215) ; M135(209)	USNM			
pallidus (Loew) (*Prohippelates*) : M74(245) ; M96(216)				
pallidus form *bilineatus* de Meij. (*Prohippelates*) : M96(216)				
pallipes Mall. (*Engycera*) : M119(182)	Cawthron			
palmyra Curran (*Scholastes*) : M129(74)				
paloloae Mall. (*Lispocephala*) : M52(88)	Bishop M			
palpalis de Meij. (*Desmometopa*) : M106(327–328)				
palpalis Mall. (*Maorina*) : M71(240)	C'bury M			
papua (Guér.) (*Euphumosia*) : M36(324) ; M107(12–13)				1 Malloch USNM ; 1 Malloch, 4 Taylor SPHTM
**papuaensis* Mall. (*Adrama*) : M123(333) ; M126(247)	SPHTM		1 USNM ; 4 BM (NH)	1 Malloch SPHTM
†*papuaensis* Mall. (*Dacus*) : M124(412)	SPHTM	USNM		1 D. E. Hardy USNM
papuensis Macq. (*Lucilia*)				14 Malloch USNM
paradoxa Dol. (*Zygaenula*) : M121(123)				
parca Bez. (*Paroxyna*) : M126(228)				
parceguttata Beck. (*Spathulina*) : M124(456–457)				
partita Mall. (*Clusiosoma*) : M124(425–426) ..	SPHTM		1 lost Malloch coll (label only)	
‡*parva* Sch. (*Amenia*) : M37(344) ; M46(614) ; M55(286)				1 Malloch Aust. M ; 3 Malloch USNM
parva Mall. (*Parahippelates*) (*Lasiopleura*) : M43(302–303) ; M128(273)				
§*parva* var. *pallipes* Mall. (*Lasiopleura*) : M128(273)	SPHTM			
parva Mall. (*Plagiostenopterina*) : M82(15) ; M121(114)	DEI			
parva Mall. (*Plecia*) : M46(606)	USNM	USNM		
parva Mall. (*Prosena*) : M67(115) ; M85(131) ..	SPHTM	USNM	3 SPHTM ; 1 USNM	
parviceps Mall. (*Sapromyza*) : M30(43)	SPHTM			
parvipuncta Mall. (*Platensina*) : M124(458–459) ..	SPHTM			
parviseta Mall. (*Actia*) : M68(308)	SPHTM		1 USNM	
parviseta Mall. (*Doddiana*) : M68(341) ; M100(139)	SPHTM			
parvula Mall. (*Phaonia*) : M6(414–415)	BM (NH)		1 BM (NH)	
passiflorae Froggatt (*Dacus*) : M81(255)				4 Malloch USNM
patula Walk. (*Lamprogaster*) : M121(140)				
pavida Hutt. (*Peremptor*) : M97(452–453) ; M119(205)				
pectinata (Loew) (*Pseudoleria*) : M31(552) ; M39(86) ; M103(183)				1 Malloch SPHTM
pectoralis Hend. (*Pterogenia*) : M121(126)				1 Malloch USNM
peculiaris Mall. (*Dacus*) : M126(235)	BM (NH)			
peculiaris Mall. (*Hobartia*) : M67(127–128) ..	CSIRO	CSIRO		
peculiaris Mall. (*Nocticanace*) : M111(4–5)	Bishop M	Bishop M	12 BM (NH) ; 2 USNM	1 G. A. K. Marshall BM (NH) ; 35 Wirth USNM
peeli Mall. (*Sarcophaga*) : M119(190)	Cawthron			
peeli Mall. (*Xenorhynchia*) : M119(190–191) ..	Cawthron		4 USNM	
pelia Sch. (*Tephritis*) : M124(461–462)				2 Malloch SPHTM ; 4 Malloch USNM
pellucens Macq. (*Rutilia*) : M44(332) ; M44(335) ; M55(301–302)				1 Malloch SPHTM
peltata (Aldr.) (*Oxysarcodexia*) : M92(14)				
peltata Aldr. (*Sarcophaga*) : M75(482) ; M92(13) ..				1 Malloch USNM
penicillata Hend. (*Eupnosopsia*) : M121(151)				
pennata Mall. (*Millerina*) : M26(140) ; M72(293)	USNM			
pepisalae Froggatt (*Dacus*) : M81(257) ; M126(242)				
perdita Mall. (*Conioscinella*) : M128(286)	SPHTM		5 SPHTM ; 2 USNM	
peregrina R.-D. (*Sarcophaga*) : M75(483)				4 Hardy SPHTM
peregrinum Meig. (*Euryomma*) : M17(146)				2 Malloch SPHTM
perfuscus Aubertin (*Chaetodacus*) (*Dacus*) : M94(145–146)				6 Malloch USNM ; 9 Malloch Bishop M
permunda Harris (*Anomoia*) : M126(275)				
pernix (Hutt.) (*Huttonophasia*) : M72(324)				
perspicax Knab (*Gitonides*) : M19(349)				1 Malloch SPHTM
perspicuus (Hutt.) (*Honualocnemis*) : M97(458) ..				3 Malloch USNM
¶*perthensis* Mall. (*Homoneura*) : M35(15)	SPHTM		1 USNM	
perturbans Mall. (*Megaselia*) : M110(335)	Bishop M		1 BM (NH)	
peterseni Mall. (*Sapromyza*) : M38(414–415) ..	USNM			
petiolata Mall. (*Wattia*) : M119(163–164)		USNM		
phaseoli Coq. (*Agromyza*) : M38(425) ; M110(340)				
phaseoli (Coq.) (*Melanagromyza*) : M111(19) ..				2 Malloch USNM
‖*philippinensis* Mall. (*Plecia*) : M46(605) ..	USNM		1 USNM	
philpotti Tonn. & Mall. (*Allophylopsis*) : M39(91) ..	Cawthron			
philpotti Tonn. & Mall. (*Eulimnia*) : M48(173) ..	Cawthron			
***philpotti* Mall. (*Protocoelopa*) : M101(346–347) ..	USNM		2 BM (NH) ; 10 USNM	

* The paratype in USNM is from Vanimo, New Guinea (Taylor), and was not mentioned in the original description.

† The allotype is labelled paratype but this was a common practice with Malloch.

‡ Although Malloch has identified specimens under this name he regarded it as a synonym of *Amenia chrysame* (see M67(101)).

§ A specimen with the data published for the type, and agreeing with the description, was found standing with a paratype of *parva*. Since the holotype of *pallipes* has not turned up anywhere, it seems likely that this is it, and it has been labelled " Probable type of *pallipes* ; in Mall. Colln. with paratype of *parva* ".

¶ The label of the USNM paratype reads 15 Nov. '24 not '25 as Malloch states. Probably a simple lapsus.

‖ The paratype in USNM is from Zamboanga, not Lamboanga as published.

** Of the paratypes in USNM, three are in fair condition, the rest very poor.

**picata* (Hutt.) (*Xeneura*): M72(339)				1 Malloch USNM; 1 Malloch C'bury M
picta (B. & B.) (*Euphasia*): M68(326–327) ..				2 Malloch USNM
pictifrons Mall. (*Typhlumyia*): M106(280–282) ..	BM (NH)	Bishop M	1 BM (NH)	
†*pictigera* Mall. (*Sapromyza*): M109(88–89) ..	SPHTM			
pictipennis Macq. (*Aphritis*): M1(236)				
pictipennis (Macq.) (*Austrodexia*): M67(123–124)..				1 Malloch SPHTM 2 Malloch USNM
pilifrons Mall. (*Sapromyza*): M30(37)	SPHTM			
piliventris Mall. (*Helina*): M9(141); M23(42) ..	BM (NH)			1 Malloch SPHTM; 3 Malloch USNM
‡*pilosa* Mall. (*Cuphocera*): M68(316–318)			1 USNM	1 Malloch SPHTM
piscivora Mall. (*Milichia*): M31(547)	SPHTM		4 USNM	
plagiata Bez. (*Epicerella*): M53(11–12); M53(25)..	SPHTM			
platycephala Mall. (*Nothoasteia*): M115(259–260)..	SPHTM			
platychirus Hend. (*Aethias*): M121(134)				
platypalpus Big. (*Atopognathus*): M122(180)				
platyptera Hend. (*Platensina*): M124(458)				
plebeia Mall. (*Actia*): M68(310)	SPHTM		2 USNM	
plebeia Mall. (*Calliphora*): M36(315)	USNM		3 USNM	1 Malloch SPHTM; 9 Malloch USNM
§*plebeia* Mall (*Coelopella*): M101(348)	USNM		3 BM (NH); 9 USNM	
plebeia Mall. (*Melanina*): M38(413)	SPHTM		3 USNM	
plebeia Mall. (*Protomiltogramma*): M69(446–447) ..	SPHTM	SPHTM	1 USNM; 1 SPHTM	
plebeia de Meij. (*Sepsis*): M25(313)				1 Malloch SPHTM; 4 Malloch USNM
¶*plebeia* Mall. (*Tephritis*): M83(393–394); M124(461)	C'bury M		8 USNM	4 F. A. Perkins BM (NH)
plebeius Fall. (*Demoticus*): M55(332)				
plebia Mall. (*Heteria*): M72(329–330)	C'bury M	USNM	12 USNM; 1 BM (NH)	
||*pleuralis* Mall. (*Brachydeutera*): M45(354) ..				4 Taylor SPHTM
pleuralis Mall. (*Clusiosoma*): M124(427); M126(259)	BM (NH)		2 USNM; 6 BM (NH)	
plumifer Ferg. (*Graptomyza*): M109(87)				
plumifera Bez. (*Rhinomyiobia*): M55(316); M110(365)				1 Malloch USNM
plumiseta Stein (*Limnophora*): M58(165)				
plumiseta Mall. (*Lispocephala*): M52(79)	Bishop M			
plumiseta Mall. (*Sapromyza*): M38(414)	CSIRO			
poecilithorax Mall. (*Drosophila*): M24(87–88) ..	SPHTM			
poeciliventris Mall. (*Helina*): M9(140); M23(42)..	BM (NH)	BM (NH)	1 BM (NH)	2 Malloch SPHTM; 2 Malloch USNM
poeciliventris Mall. (*Leucophenga*): M12(614) ..	Aust. M (headless)			
polita (Saunders) (*Angitulina*): M122(179)				
polita Mall. (*Diplotoxa*): M74(249)	Bishop M			
polita Mall. (*Hillia*): M55(328)	CSIRO			
polita Mall. (*Leucophenga*): M12(614)	Aust. M			6 Malloch USNM
polita Mall. (*Sarcophaga*): M62(270–272)	Hamburg	Hamburg	2 USNM	
politella Mall. (*Oscinis*): M116(348–349)	CSIRO			1 Malloch SPHTM
politella Mall. (*Rhamphomyia*): M83(425–426)				
politiventris Mall. (*Engycera*): M119(180–181) ..	Cawthron		2 USNM	
***politiventris* var. *setosa* Mall. (*Engycera*): M119(181)			2 USNM	
pollinosa Mall. (*Lispocephala*): M52(76)	Bishop M			
††*pollinosa* Mall. (*Rhynchomydaea*): M30(48–49)	SPHTM			
pollinosa Mall. (*Tricimba*): M38(443); M83(409)..	SPHTM		1 SPHTM; 1 USNM	
polypori Mall. (*Drosophila*): M19(351)	Aust. M		1 USNM	
pornia (Walk.) (*Rioxa*): M124(435)				2 Malloch USNM
potens (Walk.) (*Euprosopia*): M121(150)				1 Malloch SPHTM
potina Walk. (*Rutilia*): M55(304)				1 Malloch Aust. M
preapicalis (Mall.) (*Homoneura*): M35(15).. ..				1 Malloch SPHTM; 3 Malloch USNM
‡‡*preapicalis* Mall. (*Sapromyzosoma*): M25(320) ..	Lost USNM		3 USNM	
predatoris Mall. (*Lioscinella*): M134(50)	Lost SPHTM			
prima Ost.-Sack. (*Euxesta*): M96(210)				
prima Mall. (*Prosochaeta*): M113(95–96) ..	DEI			
prima (Ost.-Sack.) (*Pseudeuxesta*): M96(210); M121(98); M129(67)				1 Malloch SPHTM
prima Tonn. & Mall. (*Xenosciomyza*): M48(162–163)	Cawthron		1 ? USNM	2 F. van Emden BM(NH)
princeps (Curran) (*Erythronychia*) (*Procissio*): M97(447–448)				2 Malloch USNM
princeps Macq. (*Neosaropogon*): M43(300)				

* The two specimens recorded in M72(339) are the two identified specimens listed.

† Type is labelled *S. pictiger*.

‡ The specimen in SPHTM is from Milson I., 10.4.15. An additional label states " Returned with type by Malloch, F. H. Taylor ". Presumably the type was returned to Australia but has since been lost.

§ Of the 9 paratypes in USNM, 5 are from Invercargill, 4 from Otago. The allotype is not marked but could be one of the Invercargill specimens.

¶ The Waiho specimens (in USNM) are dated Feb. 24, not Jan. 24.

|| USNM has the two pins, each with a puparium but with no trace of the corresponding insect on the pin above the puparium. One bears Malloch's usual handwritten label " Type ". The " type adult " is apparently lost but a " type puparium " remains.

** This variety is not listed by Miller 1950 (Catalogue of the Diptera of the New Zealand Sub-Region) and it is possible that it will still be found in New Zealand.

†† It is apparent from M31(554) that Malloch intended to include this species in his genus *Hardyia*.

‡‡ In USNM the pin bearing the type label is empty, as is one other pin. Three ♀♀ are left which have been labelled paratypes. One of these may be the allotype.

prisca Ender. (*Phytalmia*) (*Archiphytalmia*): M122(172)				
prodigiosus Collin (*Ceratomerus*): M83(428)				
prominens Stein (*Pectiniseta*): M58(163); M65(327–328)				
prompta (Walk.) (*Euxestomoea*): M121(106)				
prosternalis Mall. (*Calliphora*): M107(19–20) ..	Bruxelles			
protensa (Walk.) (*Euprosopia*): M121(150) ..				1 Malloch SPHTM
proxima Tonn. & Mall. (*Allophylopsis*): M39(96)..	Cawthron			
proxima Mall. (*Lispocephala*): M60(393)	Amsterdam			
proximella Mall. (*Sapromyzosoma*) (*Homoneura*): M25(320)	SPHTM			4 Malloch USNM
pruinosa Mall. (*Euxesta*): M96(210–211)	Bishop M		2 USNM	
pseudelongata Mall. (*Lamprogaster*): M69(432–433); M121(139)	DEI		1 Aust. M	
pseudosetuligera Tonn. & Mall. (*Helosciomyza*): M48(160)	Cawthron		1 USNM	
psidii (Froggatt) (*Dacus*): M81(263); M118(115)..				2 Malloch USNM
pubiseta (Kert.) (*Homoneura*): M44(320); M59(68)				
puerula Rond. (*Leptocera*): M106(324–325); M111(23)				
pulchralis Ender. (*Colobostroter*): M124(418–419)				
pulchrifrons de Meij. (*Oscinis*) (*Lasiopleura*) (*Parahippelates*): M78(73)				1 Malloch, 27 E. T. Cresson SPHTM
pulvillata Mall. (*Limnophora*): M22(328–329) ..	SPHTM			
pumicata Wulp (*Lamprogaster*): M57(516); M121(143)				
pumila Wied. (*Lispa*): M12(608); M10(384–385); M22(334)				2 Malloch USNM
punctatifacies Tonn. & Mall. (*Poecilohetaurus*): M34(24); M38(408)	C'bury M			1 F. van Emden BM (NH)
punctatifrons Tonn. & Mall. (*Poecilohetaerella*): M34(25)	C'bury M		2 USNM	1 F. van Emden BM (NH)
punctatifrons var. *obscura* Tonn. & Mall. (*Poecilohetaerella*): M34(25)	Presumably C'bury M			
puncticeps Mall. (*Chaetolauxania*): M61(410) ..	Amsterdam			
puncticeps Mall. (*Clusiosoma*): M124(426–427) ..	SPHTM		2 USNM (almost destroyed)	
**puncticeps* Mall. (*Metallea*): M36(331)			1 ? USNM	1 Malloch SPHTM
puncticeps Mall. (*Trypaneoides*): M66(205–206) ..	Bishop M	BM (NH)		
†*punctifacies* Mall. (*Euprosopia*): M45(346–347); M57(512); M69(430)	USNM			1 Malloch USNM; 1 Malloch SPHTM
punctifacies Tonn. & Mall. (*Poecilohetaurus*): M34(24); M38(408)	C'bury M			
punctifrons Mall. (*Duomyia*): M57(510)	DEI			
punctifrons Mall. (*Macrostyla*): M128(265–266) ..	SPHTM			
punctigera Mall. (*Heteria*): M72(328)	C'bury M			
punctilabris (Bez.) (*Hemilea*): M81(265)				
punctipennis Duda (*Aprometopis*): M114(23)				
punctipennis (Duda) (*Caviceps*): M128(275) ..				1 Malloch Sabrosky Coll.
punctipennis Mall. (*Dichaetophora*): M44(323–324)	USNM		1 USNM	
punctipennis (de Meij.) (*Homoneura*): M61(413); M133(114)				
punctipennis Wied. (*Leptocera*): M106(324); M111(23)				1 Malloch SPHTM
punctipennis Wulp. (*Paradrosophila*)				1 Malloch USNM
punctiseta Mall. (*Sapromyza*): M25(317)	BM (NH)		2 BM (NH)	2 Malloch USNM
punctulata (Beck.) (*Conioscinella*): M128(282) ..				1 Malloch SPHTM; 2 Malloch USNM
punctulata Hend. (*Epicerella*): M53(12)				
punctulatus de Meij. (*Achias*): M121(137)				
purpurascens Mall. (*Hopkinsella*): M74(244) ..	BM (NH)		9 BM (NH)	
purus Beck. (*Chloromerus*): M18(332); M38(433)..				1 Malloch SPHTM; 2 Malloch USNM
purus form *maculifera* Mall. (*Chloromerus*): M38(433)				1 Malloch Sabrosky Coll.
purus form *varians* Mall. (*Chloromerus*): M38(433–434)	SPHTM		1 SPHTM; 1 USNM; 1 CSIRO	6 Malloch Sabrosky Coll.
pusilla Meig. (*Agromyza*): M24(90)				3 Malloch SPHTM
pusilla Macq. (*Atherix*): M79(274)				
pusio Wied. (*Fannia*): M58(156)				
quadrata Mall. (*Anomoia*): M124(449); M126(275)	BM (NH)	BM (NH)		
quadrata (Wied.) (*Dichaetomyia*): M27(329–330); M58(173)				
quadrifera (Walk.) (*Themaroides*): M124(419); M124(464)				
quadrilinea Walk. (*Lamprogaster*): M121(142–143)				1 Malloch SPHTM
‡*quadrilineatus* Mall. (*Chilocryptus*): M111(27); M112(188)	Bishop M	USNM		
quadrimaculata (Sved.) (*Calliphora*): M20(640); M46(613); M72(316)				3 Malloch USNM
quadrinotata Big. (*Rhinia*): M36(332)				1 Malloch SPHTM; 5 Malloch USNM
quadripunctata Mall. (*Formosia*): M67(104) ..	CSIRO		1 USNM	
quadripunctata Mall. (*Sophira*): M124(431); M126(255–257)	BM (NH)			
quadriseriata Mall. (*Melanina*): M38(413).. ..	SPHTM			

* The specimen in SPHTM agrees in data with the type series.
† One specimen in SPHTM determined by Malloch bears the name *E. picteifacies* Mall.
‡ The allotype in USNM was labelled paratype by Malloch.

quadriseriata Mall. (*Panurgopsis*): M66(211–212)..	Bishop M		2 BM (NH)	
quadriseriata Mall. (*Scaptomyza*): M112(194–195)..	Bishop M	Bishop M	2 Bishop M; 2 USNM	
quadriseta Mall. (*Actia*): M114(20)	SPHTM			2 F. van Emden BM (NH)
quadriseta Mall. (*Zealandotachina*): M119(230–231)	Cawthron		1 USNM	
quadrisetosus Bez. (*Dacus*): M81(257)				
quadristriata Beck. (*Lioscinella*): M78(64); M134(53–54)				1 Malloch SPHTM; 9 Malloch USNM and Sabrosky Coll.
quadrivittata Mall. (*Zealandotachina*): M119(231–232)	USNM			
queenslandi Ric. (*Omnatius*): M56(409)				2 Malloch USNM
radiata Hend. (*Rivellia*): M121(121)				1 Malloch SPHTM
radicum Linn. (*Egle*): M23(38); M30(48) ..				1 Malloch SPHTM
ralumensis Ender. (*Brea*): M121(125)				
ralumensis Ender. (*Mesoctenia*): M121(123)				
rapax Hutt. (*Millerina*): M72(294)				1 Malloch USNM
rara (Hutt.) (*Helosciomyza*): M7(228); M48(158)..				
rara Hutt. (*Tetanocera*): M7(228)				
raymenti Curran (*Ephydroscinis*): M78(60).. ..			3 cotypes Aust. M	
**recedens* Mall. (*Voriella*): M68(335–336); M80(298)				
recta Hutt. (*Cerosomyia*): M119(199)				
rectangularis Mall. (*Miltogramma*): M69(443) ..	SPHTM			
regalis Guér. (*Rutilia*): M44(331); M44(334); M55(302)				3 Malloch USNM; 1 Malloch SPHTM; 1 Malloch Aust. M
regalis Mall. (*Sapromyza*): M30(42)	SPHTM			
regina Mall. (*Helina*): M9(138–139); M23(41) ..	BM (NH)		5 BM (NH)	2 Malloch SPHTM; 13 F. M. Snyder USNM
regina Mall. (*Leucophenga*): M109(90)	SPHTM		5 USNM	
regina Mall. (*Macrostyla*): M128(267)	SPHTM			
regina Mall. (*Miltogramma*): M69(442–443) ..	SPHTM			
regina Hend. (*Vaupodia*): M57(513); M121(122) ..				2 Malloch SPHTM
regina Mall. (*Senostoma*): M114(14)	SPHTM		1 USNM	1 Malloch USNM
regularis Mall. (*Giraffomyia*): M129(95–96).. ..	BM (NH)			
regularis var. *perfecta* Mall. (*Giraffomyia*): M129(96–97)	BM (NH)			
repicta Schmitz (*Apiochaeta*): M110(334)				
repleta Woll. (*Drosophila*): M12(616)				1 Malloch SPHTM
reticulatus (Dol.) (*Amphicyphus*): M31(550) ..				1 Malloch USNM
rex Mall. (*Miltogramma*): M69(442)	Aust. M			
rhinoceros de Meij. (*Monocera*): M133(135)				
rhinoceros var. *nigrimana* Mall. (*Monocera*): M61(410)	Amsterdam			
rhodocera Bez. (*Hemipyrellia*): M73(237) ..				2 Malloch Hamburg
rhynchura Bez. (*Sarcophaga*): M75(481–482) ..				1 Malloch USNM
rigidiseta (Stein) (*Dichaetomyia*): M22(323).. ..				1 Malloch SPHTM; 2 Malloch USNM
rigidum (Walk.) (*Euthyplatystoma*): M121(153)				
riparia Mall. (*Sapromyza*): M35(9–10)	SPHTM		1 USNM	
rivelloides Ost.-Sack. (*Cleitamia*): M121(110)				
robusta Mall. (*Botanobia*): M134(60)	CSIRO			
robusta Mall. (*Calliphora*): M36(313)	SPHTM			
robusta Mall. (*Cerodonta*): M24(90)..	SPHTM		1 USNM	
robusta Aldr. (*Metallea*): M36(330)				
robusta Bez. (*Neotaxura*): M53(8, 23)	SPHTM			
roederi Kert. (*Cleitamia*): M121(110)				
rostrata R.-D. (*Peronia*): M31(554)				1 Malloch SPHTM; 24 Malloch USNM
rothschildi Austen (*Achias*): M121(137)				
rotundata Meig. (*Gymnosoma*): M54(112)				
rubricarinata (Macq.) (*Austrodexia*): M26(124); M67(124)				1 Malloch SPHTM; 5 Malloch USNM; series Aldrich USNM
rubriceps Macq. (*Metoponia*): M45(365)				3 Malloch, 2 Bezzi USNM
rufa Macq. (*Acinia*): M124(460)				
rufa (Stein) (*Dichaetomyia*): M22(326); M58(171); M60(405); M107(7)				3 Malloch SPHTM; 11 Malloch USNM
rufescens Duda (*Lasiopleura*): M114(24); M128(272)				2 Malloch Sabrosky Coll.
rufibasis Mall. (*Lispocephala*): M52(84)	Bishop M			
rufibasis Mall. (*Rivellia*): M129(72); M121(121)..	SPHTM		1 USNM; 2 BM (NH)	
ruficauda Hend. (*Colobostrella*): M124(446)				
ruficeps Macq. (*Urophora*): M124(460)				
ruficornis Mall. (*Anaclysta*): M12(602)	Aust. M	Aust. M	4 USNM	
ruficornis Macq. (*Microtropeza*): M55(323)				
ruficornis Macq. (*Rutilia*): M46(616–617); M55(306); M67(109)				1 Malloch SPHTM; 1 Malloch Aust. M; 7 Malloch USNM
ruficornis var. *cupreiventris* Mall. (*Rutilia*): M114(18)	SPHTM		2 USNM	
rufifacies (Macq.) (*Chrysomyia*): M20(639); M73(234)				2 Malloch SPHTM
rufifemur Mall. (*Exechopalpus*): M67(131).. ..	SPHTM		3 USNM	
rufipalpis Macq. (*Exechopalpus*): M67(130)				
rufipes Macq. (*Calliphora*): M84(66)				
rufipes Hend. (*Lamprogaster*): M121(143)				
rufipes Meig. (*Megaselia*) (*Apiochaeta*)				2 Malloch SPHTM

* This should read *Voriella uniseta* (see M80, p. 298).

rufithorax Mall. (*Adrama*): M126(249)	BM (NH)		1 BM (NH)	
rufithorax Tonn. & Mall. (*Allophylopsis*): M39(92)..	Cawthron			
rufiventris Hend. (*Euprosopia*): M121(148)				
rufiventris Macq. (*Hyalomyia*): M54(109–110)				
rufiventris Mall. (*Macropia*) (*Anaperistommyia*): M68(322–323)	SPHTM	USNM		
rufiventris (Macq.) (*Minettia*): M61(413)				
rufolateralis Mall. (*Pygidia*): M68(331)	CSIRO			
rufifrons Thoms. (*Rhytidortalis*): M121(106)				
rugosa Mall. (*Thyridula*): M31(546); M38(441); M128(274)	USNM			
rugosifrons Bez. (*Lonchaea*): M43(306)				
ruralis Meig. (*Voria*): M68(319)				2 Malloch SPHTM; 5 Malloch USNM
russelli Mall. (*Homoneura*): M133(140)	BM (NH)		4 BM (NH)	
sacra (Fabr.) (*Calliphora*): M20(640); M46(613); M72(316)				
**safuneae* Mall. (*Megaselia*): M110(334–335) ..	Bishop M		1 BM (NH)	
samoaensis Mall. (*Atherigona*): M58(159)	BM (NH)	BM (NH)		
samoaensis Mall. (*Cadrema*): M74(246)	Bishop M			
samoaensis Mall. (*Compsilura*): M110(360) ..	BM (NH)		1 BM (NH)	
samoaensis Mall. (*Isocnsia*) M66(200)	Bishop M		1 BM (NH)	
samoaensis Mall. (*Plagiostenopterina*): M73(230)..	Bishop M			
samoaensis Mall. (*Trypanoides*): M66(204–205) ..	Bishop M			
samoaensis Mall. (*Zygothrica*): M106(278–279) ..	BM (NH)	Bishop M	5 BM (NH)	
sauteri Brues (*Megaselia*): M110(337)				
sauteri Ender. (*Prototephritis*) (*Tephritis*): M124(459)				
savaiiensis Mall. (*Rutilia*): M110(350–351) ..	BM (NH)	Bishop M	1 USNM; 1 BM (NH)	
scalaris (Loew) (*Megaselia*) (*Phora*): M110(334)				
scapularis (Wied.) (*Laphria*): M46(609)				
scatophaga Mall. (*Euprosopia*): M69(431); M82(7)	SPHTM		2 USNM	
schineri Hend. (*Poecilohetaurus*): M24(84–85); M34(23); M38(408)				1 Malloch SPHTM; 6 Malloch USNM
sciomyzina Sch. (*Sapromyza*): M25(319); M34(21); M35(12)				2 Malloch SPHTM
scripta Mall. (*Paralauxania*): M38(411)	CSIRO			
scutellaris Beck. (*Chloromerus*): M116(336)				
scutellaris Beck. (*Chlorops*): M78(70–71)				
scutellaris Bez. (*Dacus*): M81(257)				
†*scutellaris* Tonn. & Mall. (*Huttonina*): M48(176–177)	Cawthron		1 USNM	
scutellata (Hutt.) (*Allophylopsis*): M39(93)				
scutellata Mall. (*Chaetopiophila*): M80(293) ..	USNM			
scutellata Mall. (*Delta*) (*Deltomyza*): M68(334) ..	SPHTM	CSIRO	1 SPHTM; 1 CSIRO; 1 USNM	
scutellata Mall. (*Euphranta*): M124(443); M126(252)	BM (NH)			
scutellata Mall. (*Fergusonina*): M24(92); M86(215)	CSIRO			
scutellata (Hutt.) (*Huttonomyia*) (*Helomyza*): M7(227)				8 Malloch USNM
scutellata Mall. (*Leucophenga*): M12(614) ..	Aust. M		1 USNM	2 A. Collart BM (NH)
‡*scutellata* Mall. (*Maorina*): M71(240–241) ..	C'bury M			2 Malloch USNM; 2 Malloch C'bury M
scutellata Mall. (*Tricimba*): M25(337–338); M38(444); M83(409)	SPHTM			
secundus Mall. (*Pachylopus*): M48(429)	SPHTM		2 SPHTM; 2 USNM	10 Malloch Sabrosky Coll.
selecta Walk. (*Adrama*): M123(334)				
semiatra Mall. (*Lioscinella*): M134(54)	SPHTM		1 SPHTM	
semibrunea Mall. (*Trigonometopus*): M66(212–213)	BM (NH)		2 BM (NH)	
semifasciata Mall. (*Euxesta*): M73(216); M96(209); M121(98)	BM (NH)			
semifumosa Mall. (*Dichaetomyia*): M60(403) ..	Amsterdam			
semifusca Mall. (*Clusiosoma*): M31(548); M124(425)	USNM	USNM	1 USNM	2 Malloch SPHTM
semimetallica Mall. (*Eucompsomyia*): M36(325)				
seminigra Duda (*Hirtodrosophila*): M106(292–293)				
seminitida Mall. (*Lispocephala*): M52(78)	Bishop M			
semirufa Mall. (*Sturmia*): M68(351–352)	CSIRO			
§*semivittata* Mall. (*Neohelina*): M21(415); M22(329)	Aust. M		1 USNM	
sensua (Curran) (*Hyalomyia*): M67(98)				
seoforalis Miller (*Huttonella*): M45(362)				
separata Hend. (*Euprosopia*): M45(344–345); M57(512); M82(8)				1 Malloch, 1 Aldrich SPHTM; 2 Malloch, 1 Aldrich USNM
sepsoides Walk. (*Elassogaster*): M45(351–352); M121(115–116)				1 Malloch SPHTM
septemnotata Mall. (*Pseudacanthoneura*): M124(434–435)	SPHTM		1 USNM	
septempunctata Mall. (*Scatella*): M111(8); M112(200)	Bishop M		2 USNM; 2 Bishop M	2 Wirth USNM
serena Meig. (*Pyrellia*): M23(46)				
seriata Mall. (*Oscinis*): M116(342)	SPHTM		1 SPHTM	
sericariae Cornalia (*Sturmia*): M110(356, 358)				
sericata (Meig.) (*Lucilia*): M36(321)				1 Malloch, 112 Paramonov SPHTM
serrata Mall. (*Drosophila*): M35(6)	SPHTM			
serratula Mall. (*Dasyrhicnoessa*): M109(94) ..	SPHTM			
sessilis Mall. (*Wattia*): M119(164)	C'bury M			
¶*setibasis* Mall. (*Vorina*): M68(321–322)	SPHTM	USNM		

* The label on the type is Samoa, Savaii, Salailua, E. J. Bryan, Jr., 23-V-24. This is not in agreement with the published locality.

† The paratype in USNM appears to be labelled "Knife and Steel" not "Knife and Fork".

‡ The specimens identified by Malloch are those recorded with a question in M71(240–1).

§ The paratype in USNM is dated 30:i:23.

¶ The allotype specimen in USNM is labelled paratype but was published as allotype.

seticauda (Mall.) (*Lasiopleura*) : M43(302); M128(273)				
setifemur Mall. (*Drosophila*) : M19(351–352).. ..	Aust. M		1 Aust. M ; 2 USNM	1 Malloch USNM
setifemur Mall. (*Epicerina*) : M120(52–53) ..	BM (NH)			
setifemur Mall. (*Idiohelina*) : M26(141–142) ; M72(304)	USNM	USNM	1 BM (NH)	
setifemur Mall. (*Prochaetops*) : M91(10) ; M112(184)	Bishop M			
setifrons Mall. (*Carpophthorella*) : M124(448) ; M126(263–264)	BM (NH)		1 BM (NH)	
**setigera* Mall. (*Austrodexia*) : M67(124–125) ..	SPHTM		3 USNM	
setigera Mall. (*Cuphocera*) : M68(318)	SPHTM		1 USNM	1 Curran BM (NH)
setigera Mall. (*Pseudocleitamia*) : M121(105) ..	BM (NH)			
setigera Mall. (*Zealandotachina*) : M119(224)				
setinervis Mall. (*Dacus*) : M118(112–113)	Bishop M		2 USNM	
setinervis Mall. (*Euprosopia*) : M121(149) ..	BM (NH)			
setitibia Mall. (*Dohrniphora*) : M25(333)	SPHTM			
†*setiventris* Mall. (*Austrodexia*) : M67(126) ..	SPHTM		1 USNM	
setiventris Mall. (*Phorocerosoma*) : M55(327) ; M68(326)	Aust. M			2 Malloch USNM
setiventris Mall. (*Plethochaetigera*) : M119(193) ..	USNM		6 USNM	
setiventris Mall. (*Pygophora*) : M60(394) ..	Amsterdam			1 probably Malloch USNM
setiventris Mall. (*Voriella*) : M110(361–362) ..	Bishop M			
setosa Bez. (*Epicerella*) : M53(12) ; M53(25–26) ..	SPHTM			
setulifera Stein (*Dichaetomyia*) : M22(323–324) ..				1 Malloch SPHTM
setuligera Mall. (*Helosciomyza*) : M7(228) ; M48(159)	Cawthron		1 USNM	1 F. van Emden BM (NH)
setulosa Mall. (*Homoneura*) : M66(210)	Bishop M			
severa Hend. (*Lamprogaster*) : M121(143)				
sexguttata de Meij. (*Acanthoneura*) : M124(464)				
sexincisa Mall. (*Tephrella*) : M124(456) ; M126(272–273)	BM (NH)			
sexmaculata Mall. (*Minettia*) : M132(20–21) ..	BM (NH)			
sexmaculata (Macq.) (*Spheniscomyia*) : M124(450) ; M126(273–274)				2 Malloch USNM
sexpunctata Mall. (*Amenia*) : M99(76–77) ..	DEI		1 Aust. M ; 1 USNM	21 D. J. Clark BM (NH)
sexpunctata Mall. (*Aneuria*) : M72(342–343) ..	C'bury M		1 USNM	
sexpunctata Mall. (*Scatella*) : M111(8)	Bishop M		1 USNM ; 1 Bishop M	
sexseriata Hend. (*Rhicnoessa*) : M111(18)				
sexsetosa Duda (*Asteia*) : M93(116)				
sexvittatus (Walk.) (*Scholastes*) : M129(74–75) ..				1 Malloch USNM
sibirita (Fabr.) (*Prosena*) : M67(114–115) ; M110(365)				2 Malloch SPHTM ; 2 Malloch USNM
sibirita var. *confusa* Mall. (*Prosena*) : M67(115) ..	SPHTM			
sigma (Walk.) (*Neolimnia*) : M48(171)				
signata (Walk.) (*Protohystricia*) : M97(431–432) ; M119(178)				
signata (Walk.) (*Hexamera*) : M119(178)				4 Malloch USNM
signata Woll. (*Siphunculina*) : M96(216) ..				1 Malloch SPHTM
signata Walk. (*Tachina*) : M97(431–432)				
signatifrons (Kert.) (*Sapromyzosoma*) : M25(321) ; M61(413) ; M133(139)				2 Malloch SPHTM ; 3 Malloch USNM (badly damaged)
signatum (Woll.) (*Microneurum*) : M96(216)				
signatus Meig. (*Pachyophthalmus*) : M69(439) ..				1 Malloch SPHTM
sikaiana Curran (*Homoneura*) : M133(142)				
similata Mall. (*Tricimba*) : M38(444) ; M83(409)..	SPHTM			
similis Kert. (*Cleitamia*) : M121(109)				
‡*similis* Tonn. & Mall. (*Ephydra*) : M34(7–8) ..	C'bury M			
similis Mall. (*Fenwickia*) : M72(338)	C'bury M	USNM		
similis (Beck.) (*Lioscinella*) : M78(66) ; M134(46)..				10 Malloch USNM and Sabrosky Coll.
similis var. *apicta* Mall. (*Lioscinella*) : M78(66) ; M134(46)	SPHTM	Presumed SPHTM	1 presumed USNM	1 Malloch USNM ; 1 Malloch Sabrosky Coll.
similis var. *femoralis* Mall. (*Lioscinella*) : M134(46)..	SPHTM		1 SPHTM ; 1 USNM	
similis var. *fuscibasis* Mall. (*Lioscinella*) : M78(66) ; M134(46)	SPHTM		1 SPHTM ; 2 USNM	
similis var. *vera* Beck. (*Lioscinella*) : M78(66)				
similis Hend. (*Pogonortalis*) : M121(120)				
similis Mall. (*Pterogenia*) : M121(126)				
simillima Tonn. & Mall. (*Sapromyza*) : M34(22) ..	C'bury M		1 USNM	
simmondsi Bez. (*Naupoda*) : M121(122)				
§*simondsi* Bez. (*Orthellia*) : M62(264)				1 Malloch USNM
simplex (Fall.) (*Leucostoma*) : M68(323–325) ..				3 Malloch SPHTM
simplex Stein (*Ophyra*) : M98(197)				
simplex Mall. (*Rutilia*) : M114(17)	SPHTM			
¶*simplex* Mall. (*Trypanea*) : M94(146–147) ..	Bishop M	USNM	1 USNM	8 F. A. Perkins BM(NH)
simplicissima (de Meij.) (*Homoneura*) : M61(413)				
simulata Mall. (*Calliphora*) : M92(16)	Bishop M	Bishop M	1 USNM	3 Malloch USNM

* One paratype from Woy Woy in USNM is dated 2.9.23 (not 1925 as stated by Malloch).

† In USNM one specimen bears no label at all except Malloch's paratype label. This is possibly a paratype with lost locality label.

‡ See note to *Ephydra assimilis*.

§ This species was published as *O. simmondsi*.

¶ A second label on the type reads *Trypanea simplissima*. The allotype and paratype listed for USNM were not labelled as such but from the data it appears clear they were intended to be.

**simulata* Mall. (*Helina*): M12(603–604); M23(41–42)	SPHTM			2 Malloch USNM
simulata Mall. (*Lioscinella*): M134(49–50)	CSIRO	CSIRO	2 CSIRO	
simulatus Mall. (*Dacus*): M126(241)	BM (NH)			
singaporensis Kert. (*Homoneura*)				1 Malloch SPHTM; 1 Malloch USNM
singularis Hutt. (*Exsul*): M13(673–674)				2 Malloch USNM
sinuata Mall. (*Graphotachina*): M119(238–239)	C'bury M			
sinuata (Don.) (*Microtropeza*): M46(614–615); M55(287); M67(100)				
skusei Bez. (*Euthera*): M55(333)				
smaragdina Mall. (*Formosia*): M55(312); M67(105)	Aust. M		1 Aust. M; 1 USNM	2 Malloch USNM
smicroides (Walk.) (*Dacus*): M124(411); M126(230)				
smithii (Hutt.) (*Limnohelina*): M72(301)				6 Malloch USNM
†*societas* Mall. (*Asteia*): M110(*a*)(91)	Bishop M	USNM		
societas Mall. (*Pectiniseta*): M65(326–327)	BM (NH)		12 BM (NH)	
solomonensis Curran (*Steganopsis*): M133(133)				
solomonensis Mall. (*Dacus*): M126(236)	BM (NH)		1 BM (NH)	
solomonensis Mall. (*Giraffomyia*): M129(93–95)	BM (NH)	BM (NH)	9 BM (NH)	2 F. van Emden BM (NH); 9 Malloch USNM
sorbens Wied. (*Byomya*): M58(174); M95(203)				2 Patton SPHTM; series Malloch Bishop M and USNM
sorbillans (Wied.) (*Thrycolyga*): M55(331–332)				
sordida Zett. (*Copromyza*): M106(323)				
sororcula (Wied.) (*Ensina*): M124(463)				
sororcula (Wied.) (*Paroxyna*): M112(200); M124(463)				1 Malloch SPHTM
sororcula Wied. (*Trypeta*): M124(463)				
sosilus (Walk.) (*Tryphera*): M119(219)				
speciosa (Erich.) (*Formosia*): M37(351); M55(309); M67(105)				2 Engel, 15 Paramonov SPHTM; 1 Malloch Aust. M; 5 Malloch USNM
speculifera Walk. (*Dacus*): M124(464)				
speighti Mall. (*Oscinosoma*): M83(413)	C'bury M		1 C'bury M; 2 USNM	
‡*spicata* Mall. (*Phytomyza*): M110(341–342)	Budapest			2 F. van Emden BM (NH)
spilariformis Mall. (*Helina*): M9(142–143); M23(43)	BM (NH)		1 BM (NH)	1 Malloch SPHTM; 12 Malloch USNM
spinicosta Mall. (*Helosciomyza*): M7(228); M48(160–161)	Cawthron			1 F. van Emden BM (NH)
spinicosta Lamb (*Polytocus*): M48(157)				
spinifemorata Mall. (*Duomyia*): M57(508–509)	DEI		2 USNM	
spiniger Stein (*Ophyra*): M95(197)				
spiniger (Wied.) (*Neoexaireta*): M45(361–362)				
spinigera Mall. (*Sapromyza*): M25(318)	SPHTM			
spinipes (Walk.) (*Limnohelina*): M72(297)				8 Malloch USNM
spinulenta Collin (*Hilara*): M83(427)				2 Malloch USNM
splendida Don. (*Rutilia*): M37(347); M44(333); M55(297)				1 Malloch, 5 Engel, 5 Paramonov SPHTM; 1 Malloch Aust. M; 2 Malloch USNM
stabulans (Fall.) (*Muscina*): M12(601)				1 Malloch, 1 Marshall SPHTM; 1 Malloch USNM
stagnalis (Fall.) (*Scatella*): M111(7)				8 Malloch USNM (Marquesas)
stenoparia Hend. (*Lamprogaster*): M45(350); M57(515); M121(144)				1 Malloch SPHTM; 2 Malloch USNM
sternalis Mall. (*Calliphora*): M84(65)		SPHTM	4 USNM	
sternopleuralis Mall. (*Limnophora*): M65(332–333)	BM (NH)	BM (NH)	1 BM (NH)	
sternopleuralis Mall. (*Lioscinella*): M124(53)	SPHTM			
stictica Sch. (*Amenia*): M37(342); M99(75)				
stiglinae Bez. (*Actia*): M110(364)				
stigmatella (Beck.) (*Oscinis*): M78(71); M116(339)				2 Malloch Sabrosky Coll.
stigmatica Mall. (*Sapromyza*): M30(42); M35(12)	SPHTM			1 Malloch SPHTM
stirlingi Mall. (*Paralimna*): M31(545–546)	BM (NH)		3 BM (NH)	
stolida Mall. (*Chaetogastrina*): M55(313–314)	Aust. M		3 Aust. M	6 Malloch USNM
stolida Mall. (*Pollenia*): M114(21–22)	SPHTM	SPHTM	1 SPHTM; 2 USNM	
strahani Mall. (*Sapromyza*): M38(417–418)	CSIRO			
stramineipes Mall. (*Scaptomyza*): M106(295–296)	Bishop M			
striata (Hutt.) (*Neolimnia*): M48(169)				
§*striata* var. *brunneifrons* Tonn. & Mall. (*Neolimnia*): M48(169)				
striatifrons (Beck.) (*Chloromerus*): M78(68)				17 Malloch USNM and Sabrosky Coll.
striatipennis Mall. (*Depressa*): M38(401–402)	CSIRO			
strigatus de Meij. (*Achias*): M121(134)				

* One of the determined specimens in USNM is wrongly labelled paratype.

† In the original description both male and female were described but no type was designated, nor was the number of specimens indicated. Sabrosky has clarified the position as follows. "Two specimens were found in the Malloch Collection, a male bearing Malloch's 'type' label (but dated Aug. 23, 1928) and a female (Sept. 11, 1928). The male was described in detail and was obviously intended to be the type. To be definite, I have labelled the two specimens "Lectotype ♂" and "Lectoallotype ♀". This is intended to be taken as publication of this adjustment.

‡ A species originally described from Formosa (*Ann. Mus. Nat. Hungar.*, 12: 334 (1914)).

§ This variety is not listed by Miller 1950 (Catalogue of the Diptera of the New Zealand Sub-Region) and it is possible that the type will still be found in New Zealand.

strigipes Mall. (*Batrachomyia*): M38(441); M128(264)	CSIRO			
strumosa Bez. (*Epicerella*): M53(13); M53(26) ..	SPHTM			
stygia (Fabr.) (*Calliphora*): M36(308–309); M46(613); M72(316); M84(65)				4 Malloch, 3 Taylor SPHTM; 6 Malloch USNM
stylops Ender. (*Laglaisia*): M121(113)				
subaeneiventris Mall. (*Sapromyza*): M30(37–38) ..	SPHTM			3 Malloch USNM
subalpina Tonn. & Mall. (*Helosciomyza*): M48(158–159)	Cawthron			
subapicalis (Macq.) (*Stomatorhinia*): M36(333–334)				1 Malloch SPHTM 6 Malloch USNM
subarcuata Mall. (*Oscinis*): M116(347–348) ..	SPHTM			
subdita Collin (*Hilarempis*): M83(427)				1 Malloch USNM
subnitida Mall. (*Drosophila*): M35(5)	SPHTM			
subnotata Mall. (*Chloropisca*): M38(429–430); M116(354)	SPHTM		1 SPHTM	1 Malloch SPHTM
subnuda Mall. (*Homoneura*): M133(141–142) ..	BM (NH)			
subnudus Mall. (*Achias*): M121(134–135)	BM (NH)	BM (NH)	9 BM (NH)	
subobsoleta Mall. (*Limnophora*): M58(169).. ..	BM (NH)		1 BM (NH)	
subopacifrons Mall. (*Lioscinella*): M134(56–57) ..	SPHTM	SPHTM	12 SPHTM; 1 CSIRO	
subpolita Mall. (*Limnophora*): M65(330)	BM (NH)		3 BM (NH)	
subscutellata Tonn. & Mall. (*Allophylopsis*): M39(93–94)	Cawthron			
subsessilis Mall. (*Palpostoma*): M80(297)	SPHTM (fragmentary)	SPHTM (damaged)	8 USNM; 4 SPHTM (damaged)	
subspinicosta Tonn. & Mall. (*Helosciomyza*): M48(161)	Cawthron		1 USNM	
subtilis Hutt. (*Macquartia*): M97(434)				4 Malloch USNM
subtilis (Hutt.) (*Zealandotachina*): M119(226)				
subvittata Mall. (*Caricea*): M22(332–333)	SPHTM			
subvittata Mall. (*Lispocephala*): M52(88)	Bishop M			
suffusa Mall. (*Dichaetomyia*): M60(406–407) ..	Amsterdam			
suffusa Mall. (*Oscinis*): M116(350–351)	CSIRO			
suffusa Mall. (*Sapromyza*): M30(37)	SPHTM			
sulcata (Beck.) (*Oscinis*): M116(344)				1 Malloch SPHTM
sulfurigaster Duda (*Drosophila*): M106(311)				
sumbana Ender. (*Platensina*): M124(458)				
**surcoufi* Bez. (*Paratricyclea*): M36(323)				1 Malloch, 2 Taylor SPHTM; 1 Malloch USNM (under a manuscript name)
surda Curran (*Minettia*): M133(144)				
suspensa Mall. (*Homoneura*): M133(141)	BM (NH)			
suttoni Mall. (*Themarohystrix*): M124(423) ..	SPHTM		3 USNM	
suturalis Stein (*Limnophora*): M107(7)				
suturalis Mall. (*Lioscinella*): M134(51)	SPHTM			
†*sydneyensis* Mall. (*Brachydeutera*): M18(335) ..	SPHTM		1 USNM	3 Malloch USNM
sydneyensis Mall. (*Chloropisca*): M116(354) ..	SPHTM			
sydneyensis Mall. (*Cylindromyia*): M68(314–315)..	CSIRO			
sydneyensis Mall. (*Drosophila*): M35(5–6) ..	SPHTM		2 USNM	
sydneyensis Sch. (*Xenolispa*): M12(610)				2 Malloch SPHTM; 4 Malloch USNM
sydneyensis Mall. (*Xenosepsis*): M25(315) ..	SPHTM		1 USNM (headless)	
taeniata Wulp (*Lamprogaster*): M121(145)				
‡*tahuatae* Mall. (*Prochaetops*): M91(12); M112(187)	Bishop M		1 presumed USNM	2 Malloch USNM
taitensis Sch. (*Sarcophaga*): M64(256–257); M92(13)				Series Malloch Bishop M and USNM
§*tarsalis* Mall. (*Asteia*): M93(116); M112(190)	Bishop M			1 Malloch USNM
tarsalis Loew (*Desmometopa*): M106(327)				? 1 Hill, ? 1 Brit. M, SPHTM
tasmaniensis Mall. (*Aphiochaeta*): M2(514) ..	USNM		15 USNM (labelled "cotypes")	
tasmaniensis Mall. (*Ceratolauxania*): M38(408–409)	SPHTM			
¶*tasmaniensis* Mall. (*Diploloxa*): M38(434) ..	CSIRO		1 USNM	
tasmaniensis Mall. (*Helina*): M9(138); M23(41) ..	BM (NH)			2 Malloch USNM
tasmaniensis Mall. (*Incurviseta*): M38(406).. ..	CSIRO		2 USNM; 1 CSIRO	
tasmaniensis (Mall.) (*Lioscinella*): M78(62); M134(51)				1 Malloch Sabrosky Coll.
tasmaniensis Mall. (*Oscinosoma*): M78(62).. ..	SPHTM	SPHTM	1 SPHTM	
||*taylori* Mall. (*Lasiopleura*): M128(273)	SPHTM		1 USNM	
taylori Mall. (*Pseudosphenisus*): M124(450–451)..	SPHTM	BM (NH)		
taylori Mall. (*Scholastes*): M121(129–130) ..	SPHTM		2 USNM	1 Malloch Aust. M
taylori Mall. (*Tapeigaster*): M109(94–95)	SPHTM			
tectamus Walk. (*Andrenosoma*): M43(299)				

* A type specimen in SPHTM labelled *P. australis* Mall. from Melville Island, N.T. (G. F. Hill) appears to be the specimen mentioned as *P. surcoufi* in M36(323).

† The paratype listed for USNM is from Belaringar, N.S.W., 9.9.23. The three specimens listed for USNM as mentified by Malloch are on one mount with a paratype label but are from Eidsvold, Q., 1924, Bancroft, and are not identioned in the original description so can only be considered as identified specimens.

‡ The presumed paratype in USNM is from the correct locality but the other data are 1750 ft., July 9, 1930. The two specimens recorded in M112(187) were erroneously labelled paratypes by Malloch.

§ The specimen recorded in M112(190) is in USNM erroneously labelled paratype by Malloch.

¶ The ♀ in USNM is marked paratype but is presumably the allotype published by Malloch.

|| "Presumed holotype" and "presumed paratype" found unlabelled in Malloch Collection. (Type to be returned to SPHTM, paratype in USNM, labelled as above.) These two specimens stood unlabelled with other *Lasiopleura*. I realized when I came to identify them that they are undoubtedly the holotype and paratype of *L. taylori*. The data on the labels agree exactly with the published information, and the paratype is greasy as stated (C. W. Sabrosky).

tegularia Mall. (*Euprosopia*) : M45(347)	USNM		1 USNM	
telescopia Ender. (*Laglaisia*) : M121(113)				
temerarum (Hutt.) (*Calcager*) (*Campylia*) : M119(239–240)				13 Malloch USNM (6 as *Calcager*, 7 as *Campylia*)
tenebrosus Walk. (*Cephaloconus*) : M125(448–449) ..				1 Malloch USNM
tenera Loew (*Tephritis*) : M124(460)				
tentaculata de Geer (*Lispa*) : M58(153)				
tenuicornis Macq. (*Euprosopia*) : M46(612) ; M69(430) ; MS2(7)				1 Malloch SPHTM ; 2 Malloch USNM
tenuicornis Mall. (*Melanochelia*) : M13(673) ..	BM (NH)		1 USNM	7 Malloch USNM ; 4 Malloch C'bury M
tenuicornis Mall. (*Sapromyza*) : M35(8–9) ..	SPHTM			
tenuipennis Mall. (*Trypaneoides*) : M71(244)				
tenuis Mall. (*Exsul*) : M13(674)	USNM	Presumed USNM	1 presumed USNM ; 1 BM (NH)	1 F. van Emden BM (NH) ; 3 D. J. Clark (BM (NH) ; 1 Malloch USNM ; 1 Malloch SPHTM
tenuis Mall. (*Prosena*) : M67(114)	SPHTM			
tenuis Mall. (*Zealandotachina*) : M119(232–233) ..	C'bury M	USNM	3 USNM	
tephrura Bez. (*Sarcophaga*) : M62(269–270) ..				1 Malloch USNM
tepunae Mall. (*Limnophora*) : M95(199)	Bishop M			
termitoxena (Bez.) (*Termitorioxa*) : M124(436) ..				1 Bezzi, 1 Hill SPHTM ; 1 Malloch DEI
**terraereginae* Mall. (*Dichaetomyia*) : M22(325) ..	BM (NH)	SPHTM	7 BM (NH) ; 4 USNM ; 2 SPHTM	1 Malloch SPHTM
terrae-reginae Mall. (*Elassogaster*) : M45(352) ; M82(22) ; M121(116)	SPHTM	SPHTM	4 SPHTM ; 4 USNM	
territa Ost.-Sack. (*Calobata*) : M110(343)				
territa (Ost.-Sack.) (*Grammicomyia*) : M110(343)				
testacea (Mall.) (*Efftatyloria*) (*Tayloria* in M67) : M67(98–99) ; M134(64)	SPHTM		1 USNM	
testacea Big. (*Gramnicomyia*) : M110(343)				
testacea Mall. (*Homoneura*) : M38(419–420) ..	CSIRO	USNM		
testacea R.-D. (*Palpostoma*) : M37(338)				
testacea (Macq.) (*Prodiaphania*) : M37(352) ..				1 Malloch Aust. M
testacea R.-D. (*Rhinia*) : M32(504)				1 Malloch SPHTM ; 2 Malloch USNM
testacea Hend. (*Rioza*) : M124(435–436)				
testacea Macq. (*Senostoma*) : M37(351–352) ; M55(292) ; M114(12–13)				4 Malloch USNM
testacea var. *claripennis* Mall. (*Senostoma*) : M55(292)	Aust. M			1 Malloch USNM
testacea var. *testacea* Macq. (*Senostoma*) : M55(292) ..				1 Engel SPHTM ; 1 Malloch Aust. M
testaceipes (Kert.) (*Homoneura*) : M59(58)				
tetanocerina Hend. (*Ceratolauxania*) : M38(409)				
tetyroides (Walk.) (*Asyntona*) : M121(122) ..				1 Malloch SPHTM ; 2 Malloch USNM
thoracalis Hend. (*Achias*) : M121(136)				
†*thoracica* Mall. (*Tephritis*) : M33(392–393) ..	C'bury M		3 USNM	
tibialis Macq. (*Calliphora*) : M36(308) ; M46(613) ; M84(65)				4 Malloch, 7 Taylor, 1 Patton SPHTM ; 1 Malloch USNM
tibiella Beck. (*Lioscinella*) : M134(56)				
tibiseta Mall. (*Atherigona*) : M17(145–146) ..	Aust. M			6 Malloch USNM ; 2 Malloch SPHTM
tibiseta Mall. (*Tethina*) : M109(91–92)	SPHTM		7 USNM ; 1 BM (NH)	
tigrina Ost.-Sack. (*Euprosopia*) : M57(513) ; M121(147)				
tillyardi Mall. (*Froggattimyia*) : M104(6)	CSIRO			
tincticornis Mall. (*Botanobia*) : M134(62)	CSIRO	SPHTM	3 SPHTM ; 1 CSIRO	
tinctipennis Mall. (*Eutricimba*) : M83(408–409) ..	C'bury M			
tinctipes (Mall.) (*Lioscinella*) : M78(63) ; M134(56)				
tomentosa (Hend.) (*Duomyia*) : M57(507)				
tongensis Froggatt (*Dacus*) : M81(263)				
tonnoiri Mall. (*Asteia*) : M71(233)	C'bury M			
tonnoiri (Mall.) (*Botanobia*) : M78(62) ; M134(58)				
tonnoiri Mall. (*Genotrichia*) : M119(164–165) ..	Cawthron			
tonnoiri Mall. (*Oscinosoma*) : M78(62)	SPHTM			
tonnoiri Mall. (*Paracoenosia*) : M119(254–256) ..			2 USNM	
tonnoiri Mall. (*Sapromyza*) : M38(417)	CSIRO		2 USNM ; 1 CSIRO	
tonsa (Stein) (*Heliographa*) : M60(399)				
townsvillensis (Tayl.) (*Pericoma*) : M3(265)				
toxopei Mall. (*Homoneura*) : M61(412)	Amsterdam			
toxopei Mall. (*Xenosina*) : M60(399)	Amsterdam			
tranquilla (Hutt.) (*Neolimnia*) : M48(171)				
transversa Mall. (*Rutilia*) : M114(15–16)	SPHTM		1 USNM	
transversalis Mall. (*Rhinomyiobia*) : M67(130) ..	SPHTM			
triangularis Mall. (*Epicerella*) : M53(26)	USNM			
triangulifera Mall. (*Semisuturia*) : M37(342) ..	USNM	USNM (presumed)	1 BM (NH)	
trichopareia Sch. (*Winthemia*) : M68(349) ; M110(359)				3 Malloch SPHTM
tricolor Mall. (*Agromyza*) : M38(427–428)	USNM	USNM		
tricolor Mall. (*Calotachina*) : M119(176–177) ..	Cawthron			
tricolor Mall. (*Cylindromyia*) : M68(315–316) ..	SPHTM			

* A paratype in USNM was labelled so by Malloch but the other information is only " N.S.W., Aust."
† The Ben Lomond paratype (in USNM) is labelled 25.11.12, not Dec. 20, 1923.

tricurvata (Walk.) (*Cleitamia*): M121(109)				
trifasciata (Dol.) (*Chaetorivellia*): M121(127)				
trifasciata Mall. (*Chrysotrypanea*): M124(457–458)	SPHTM			
trifasciger Mall. (*Leptocera*): M44(326)				
trigonalis de Meij. (*Cleitamia*): M121(112)				
trilineata Hutt. (*Apterina*): M102(261)				
trilineata de Meij. (*Diplochorda*): M122(176–177)				1 Malloch SPHTM
trimaculata Mall. (*Chloromerus*): M38(433) ..	SPHTM			
trinubilifera Mall. (*Helina*): M9(141); M23(42) ..	BM (NH)		1 BM (NH)	
**tripuncta* Mall. (*Lispocephala*): M52(80)	Bishop M		1 USNM	
tripunctata Mall. (*Aneuria*): M72(342)	C'bury M		1 USNM	
tripunctata Dol. (*Eumorphomyia*): M53(3)				
tripunctifacies Mall. (*Steganopsis*): M133(132) ..	BM (NH)			
trisignata Wulp (*Lamprogaster*): M121(143)				
trispina Mall. (*Agromyza*): M38(425)	SPHTM			
tritici Coq. (*Hydrellia*): M25(327); M34(14–15) ..	1 cotype USNM			1 Malloch SPHTM; 10 Malloch USNM
trochanterata Mall. (*Ophyra*): M95(196–198) ..	Bishop M		16 Bishop M; 9 USNM	
tryoni (Froggatt) (*Dacus*): M81(263)				3 Malloch USNM
turbidum (Hutt.) (*Plagiomyia*): M119(169–170) ..				4 Malloch USNM
uahukae Mall. (*Heterodoxa*): M96(214)	Bishop M			
uahukae Mall. (*Oscinosoma*): M96(217)	Bishop M			
†*uapouae* Mall. (*Heterodoxa*): M96(212–213) ..	Bishop M	Presumed USNM		
umbrinervis Stein (*Phaonia*): M17(141)				1 Malloch SPHTM; 2 Malloch USNM
umbrosus Fabr. (*Dacus*): M81(259); M124(412); M126(236)				3 Malloch SPHTM
unguiculata Mall. (*Chaetoscatella*): M106(322–323)	BM (NH)			
‡*unguiculata* Tonn. & Mall. (*Scatella*): M34(10–11)	C'bury M			1 Tonnoir USNM
unica Mall. (*Cheesmanomyia*): M124(420) ..	BM (NH)			
unicolor Hend. (*Dacus*): M126(230)				
unicolor Mall. (*Hirtodrosophila*): M106(293) ..	BM (NH)		3 BM (NH)	
unicolor Hend. (*Paranomina*): M38(402)				
unicolorata Mall. (*Sapromyza*): M30(44)	SPHTM			
unifasciatus Mall. (*Dacus*): M126(233–234) ..	BM (NH)			
uniformis Mall. (*Dichaetomyia*): M60(407) ..	Amsterdam			
uniformis Mall. (*Limnohelina*): M72(299)	C'bury M	USNM		
uniformis Mall. (*Lonchaea*): M74(242)	Bishop M			
unifrons Mall. (*Lioscinella*): M134(47–48) ..	USNM			
unimaculata (Mall.) (*Cadrema*): M128(278)				
unimaculata Mall. (*Hippelates*): M38(439) ..	CSIRO			
§*unimaculata* Mall. (*Trypanea*): M83(403) ..	C'bury M		1 USNM	
unipuncta Mall. (*Austrodexia*): M67(128)	SPHTM		2 USNM	1 Curran SPHTM; 2 Curran BM (NH)
unipuncta Mall. (*Prochaetops*): M91(7–8); M112(184)	Bishop M			
unipunctata Mall. (*Deltastoma*): M19(359); M128(275)	SPHTM			
unipunctatus Mall. (*Dacus*): M126(245–246) ..	BM (NH)			
¶*uniseta* Mall. (*Lispa*): M10(389); M12(609); M22(335); M25(340)	BM (NH)		1 BM (NH)	4 Malloch USNM
uniseta Mall. (*Lonchaea*): M74(243) ..	Bishop M		1 BM (NH)	
uniseta Mall. (*Paratinna*): M25(325) ..	SPHTM			
uniseta Mall. (*Voriella*): M68(335–336); M80(298)	CSIRO	SPHTM	3 SPHTM; 1 USNM; 1 CSIRO	
unistriata Mall. (*Diplochorda*): M122(179) ..	BM (NH)		12 BM (NH)	
upoluae Mall. (*Drosophila*): M106(305–306) ..	BM (NH)			
upoluae Mall. (*Sturmia*): M110(354–355) ..	Bishop M		3 BM (NH)	
urbana Mall. (*Hylemia*): M17(139)	SPHTM		2 USNM	
urbana Mall. (*Sapromyza*): M35(10–11)	SPHTM			
usitata (Hutt.) (*Cerosomyia*): M119(196–198) ..				2 Malloch USNM
ustipennis Mall. (*Atherigona*): M95(201–202) ..	Bishop M		2 USNM; 2 Bishop M	
valentina Macq. (*Amphibolia*): M37(349); M53(312)				1 Malloch Aust. M; 1 Paramonov SPHTM
valida Curran (*Actia*): M68(305)				
valida Hutt. (*Procissio*): M119(204)				5 Malloch USNM
vandiemeni Mall. (*Conioscinella*): M128(285) ..	SPHTM	USNM		
vandiemeni Mall. (*Helina*): M13(672); M23(42)	BM (NH)		2 BM (NH)	2 Malloch USNM
varia Kert. (*Homoneura*): M133(142)				
‖*varia* Curran (*Prosena*): M80(298); M85(130) ..				2 Malloch, 1 Curran SPHTM; 1 Malloch USNM
variabilis Bez. (*Prodalmannia*): M53(19–20; 30)	SPHTM	SPHTM		1 Malloch USNM
variabilis Kert. (*Ptilona*): M124(464)				
varians Mall. (*Calcageria*): M119(173)	C'bury M		1 USNM	
variceps Mall. (*Perrissina*): M119(187)	Cawthron			
varidorsata Mall. (*Lioscinella*): M134(51–52) ..	SPHTM	SPHTM	21 USNM	
variegata (Big.) (*Euphumosia*): M107(14–15)				
variegata Curran (*Prosena*): M80(298); M85(132)	SPHTM			
variegata Hendel (*Neotoxura*): M53(7, 23) ..				1 Bezzi SPHTM

* The paratype in USNM has the same data as published for the type but was not published as such.
† The specimen considered to be allotype is labelled paratype but agrees with the published data except for the date, Jan. 29, 1930.
‡ The USNM specimen is labelled "A. Tonnoir det." and has the same data as published for the allotype.
§ The paratype in USNM is the Kumara specimen, not designated as paratype in the original description.
¶ Of the four determined specimens in USNM one is labelled "allotype", apparently based on M25(340).
‖ There is an additional specimen in USNM determined by Malloch as *varia* var.?

*varifrons Mall. (*Calliphora*): M84(66–67) ..		? USNM		3 Malloch SPHTM
varimana Mall. (*Steganopsis*): M133(133)	BM (NH)			
†*varipalpis* Mall. (*Desmometopa*): M35(7–8) ..	SPHTM (presumed)			
varipennis Mall. (*Scatella*): M111(9)	Bishop M			
varipes Mall. (*Batrachomyia*): M128(264–265) ..	DEI			
‡*varipes* Mall. (*Dacus*): M126(240–241)	BM (NH)	BM (NH)	1 USNM; 1 BM (NH)	
varipes Mall. (*Medinella*): M119(237)	C'bury M	USNM	1 USNM	
varipes (Macq.) (*Microcalliphora*): M36(326) ..				1 Malloch SPHTM
varipes Mall. (*Pseudotrichopoda*): M99(78–79) ..	DEI			
varipes Mall. (*Zealandotachina*): M119(227–230) ..	Cawthron			
varipes var. *varipes* Mall. (*Zealandotachina*): M119(228–229)			3 USNM	
varipes var. *fumata* Mall. (*Zealandotachina*): M119(229)	Cawthron		1 USNM	
varipes var. *fuscata* Mall. (*Zealandotachina*): M119(229)	C'bury M		1 USNM	
§*varipes* var. *strigipes* Mall. (*Zealandotachina*): M119(229)	Cawthron			
varipes var. *lata* Mall. (*Zealandotachina*): M119(229–230)	C'bury M			
¶*variseta* Mall. (*Oscinis*): M116(345–346)	SPHTM		1 USNM	
variventris Mall. (*Sapromyza*): M30(38–39); M35(12)	SPHTM			1 Malloch SPHTM
varivitta Mall. (*Oscinis*): M116(349–350)	SPHTM			
velutina Mall. (*Erythronychia*): M97(444)	Cawthron	USNM	1 USNM	
velutifrons Tonn. & Mall. (*Hydrellia*): M34(15) ..	C'bury M			
ventralis (Walk.) (*Euprosopia*): M121(150–151)				
ventralis Curran (*Naupoda*): M129(75)				
venusta Coq. (*Diploneura*): M110(329)				
venustulus Walk. (*Achias*): M121(134)				
verecunda (Hutt.) (*Huttonobesseria*): M83(385–386)				}8 Malloch USNM
verecunda Hutt. (*Phania*): M83(385–386) ..				
vernalis White (*Atherimorpha*): M79(275–276) ..				1 Hardy SPHTM
versicolor Curran (*Amplipila*): M55(336)				
versicolor B. & B. (*Chrysopasta*): M46(616)				
versicolor Stein (*Helina*): M23(43)				
versicolor Mall. (*Lispocephala*): M106(287–289) ..	BM (NH)	Bishop M	3 BM (NH)	
versutus Hutt. (*Occisor*): M119(206)				
vetutissima Walk. (*Byomyia*): M58(174); M49(333–334)				1 Austen SPHTM
vexata Hutt. (*Macquartia*): M97(435); M119(221)				4 Malloch USNM
viatrix (de Meij.) (*Homoneura*): M133(139)				
vicarians Sch. (*Anthomyia*): M23(37)				2 Malloch USNM
vicina Macq. (*Musca*): M95(203)				
victoria Mall. (*Helina*): M9(141–142); M23(42) ..	BM (NH)		1 BM (NH)	
victoriae Hill (*Actina*): M45(364)				
victoriae Mall. (*Sapromyza*): M25(317–318) ..	SPHTM			1 Tonnoir USNM
victoriae Mall. (*Senostoma*): M114(13–14)	SPHTM		2 USNM	1 Malloch USNM
villosa R.-D. (*Calliphora*): M20(640)				3 Malloch USNM (as *Neopollenia villosa*)
viola Mall. (*Lamprogaster*): M57(515–516)	DEI		1 Aust. M	
violacea Macq. (*Chaetogaster*): M37(353); M55(315); M114(19)				1 Malloch, 4 Paramonov SPHTM; 1 Malloch USNM
violacea Ender. (*Giraffomyia*) (*Meachina*): M122(179)				
virgatus Collin (*Ceratomerus*): M83(428)				
virgatus Coq. (*Dacus*): M81(264)				
virgo Hendel (*Rivellia*): M70(492)				2 Malloch USNM
viridana Mall. (*Incurviseta*): M38(407–408) ..	CSIRO		1 USNM	
viridinigra Macq. (*Rutilia*): M44(332, 334); M55(302)				1 Malloch Aust. M; 1 Malloch USNM
viridis Mall. (*Chaetogaster*): M114(19)	SPHTM			
viridis Towns. (*Chlororhinia*): M32(498); M36(332); M55(283)				1 Malloch SPHTM; 1 Malloch Aust. M; 5 Malloch USNM
viridiventris Mall. (*Xenocalliphora*): M72(318) ..	C'bury M			
viridula Mall. (*Incurviseta*): M38(408)	CSIRO		1 USNM	
vittata Curran (*Peremptor*): M55(343); M97(436); M97(454)				
vittata Macq. (*Prosena*): M67(116)				
vittata Mall. (*Stomosis*): M24(89)	SPHTM		1 USNM	1 Malloch USNM; 1 Ferguson SPHTM
vittatus Macq. (*Aphritis*): M1(236)				
vittigera Mall. (*Cerodonta*): M38(423–424) ..	SPHTM			
vittigera Mall. (*Incurviseta*): M38(405–406) ..	CSIRO			
vittigera Mall. (*Trypanea*): M83(400)	C'bury M			
vittipennis de Meij. (*Grammicomyia*): M110(343)				
vittithorax Mall. (*Scatella*): M25(331)	SPHTM		1 USNM	1 Ferguson SPHTM
vittithorax Mall. (*Trypanocentra*): M124(429) ..	BM (NH)			

* The ? allotype in USNM is labelled merely "*Calliphora varifrons* Mall." Its sex and data agree with the details published for the allotype.

† A specimen labelled "*Desmometopa varicornis* Type" agrees perfectly, in description and in specimen data, with *D. varipalpis* (M35, pp. 7–8). It seems almost certain that this is the type of *D. varipalpis*. Malloch did err in saying that the specimen was a female, though he could scarcely tell from the condition of the specimen.

‡ The paratype in USNM is dated 24.v.1934, not 14.v.1934 as published.

§ USNM has three specimens marked "*strigipes* paratype" by Malloch which are the Mt. Ida and two without locality cited under the second "*fuscata*" on p. 229. Malloch apparently got the text mixed up here.

¶ Paratype in USNM. Date is actually Nov. 25, not 15; the "2" is poorly printed.

vicipara (Fabr.) (*Rutilia*): M37(346); M44(331); M44(333); M55(298)				19 Paramonov SPHTM; 1 Malloch Aust. M; 2 Malloch USNM
vicipara Port. (*Vicipuromusca*): M23(46)				
wallacei Saunders (*Elaphomyia*): M122(180)				
wallacei (Mall.) (*Homoneura*): M59(58)				
wallacei Mall. (*Griphoneura*): *Ann. Mag. Nat. Hist.*, ser. 9, 16: 362	BM (NH)			
wallacei (Saunders) (*Phytalmia*): M122(172) ..				1 Malloch Aust. M
wallacei Hendel (*Pseudepicausta*): M121(119)				
waterhousii Mall. (*Lioscinella*): M134(48)	SPHTM		1 USNM	
watti Tonn. & Mall. (*Poecilohetaerella*): M34(26)				
watti Mall. (*Trypanea*): M83(403–404)	C'bury M		1 USNM	1 F. A. Perkins BM (NH)
wentworthi Mall. (*Froggattimyia*): M104(3–4) ..	SPHTM			
weschei Mall. (*Lispa*): M10(389); M12(609); M22(334)	SPHTM			4 Malloch SPHTM; 2 Malloch USNM
whitei Mall. (*Helina*): M9(137); M23(41) ..	BM (NH)	BM (NH)		
whitei Hardy (*Pachygaster*): M45(366)				
willeyi Sharp (*Giraffomyia*): M122(179); M129(93)				
wilmoti Mall. (*Incurviseta*): M38(404)	CSIRO		1 USNM	
wolffi Cresson (*Tephritis*): M124(460)				
wollastoni Edwards (*Phytalmia*): M122(170)				
xanthina Speiser (*Phora*) (*Megaselia*): M110(334)				
xanthocera Mall. (*Calliphora*): M36(313)				
xanthodes Broun (*Dacus*): M81(260)				
xanthogaster Wied. (*Rhinia*): M46(612–613)				
xanthogaster Wied. (*Stomatorhinia*): M36(334)				
xanthoptera Hendel (*Lamprogaster*): M45(349); M57(515); M121(143)				4 Malloch USNM
**xanthopyga* Mall. (*Perrissina*): M119(187) ..	Cawthron		1 USNM	
xenia Mall. (*Sapromyza*): M109(87–88)	SPHTM			
xenina Mall. (*Lispocephala*): M52(79)	Bishop M			
†*xenochaeta* Mall. (*Lispa*): M12(608); M22(334) ..	SPHTM			4 Malloch USNM
xiphophora Bez. (*Paurothrix*): M73(235)				
zabrina (Walk.) (*Chrysopasta*): M55(307); M67(106)				
zebina Walk. (*Sturmia*): M110(357–358)				
zelotypa Hendel (*Lamprogaster*): M45(350); M57(515); M121(141–142)				1 Malloch SPHTM; 1 Malloch USNM

* USNM has the "second specimen" cited by Malloch. He labelled it a paratype though it was not so stated in the publication.

† The four determined specimens in USNM are incorrectly labelled paratypes.

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(N.B.—The serial numbers M1 to M135 preceding each reference are the symbols by which each reference is cited in the family, genera and species lists.)

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ABSTRACT OF PROCEEDINGS

ORDINARY MONTHLY MEETING.

30th March, 1955.

Dr. F. V. Mercer, President, in the chair.

Library accessions amounting to 51 volumes, 394 parts or numbers, 43 bulletins, 15 reports and 56 pamphlets, total 559, had been received since the last meeting.

PAPERS READ (by title only).

1. The *Culex pipiens* Group in South-eastern Australia. IV. Cross-breeding Experiments within the *Culex pipiens* Group. By N. V. Dobrotworsky.

2. Chromosome Numbers and Pollen Tetrad Size in the Winteraceae. By A. T. Hotchkiss.

3. A Note on the Faecal Flora of some Antarctic Birds and Mammals at Macquarie Island. By J. S. Bunt.

4. The Nymph of *Euschöngastia perameles* (Womersley, 1939): Acarina, Trombiculidae. By R. Domrow.

ORDINARY MONTHLY MEETING.

27th April, 1955.

Professor J. M. Vincent, Vice-President, in the chair.

Dr. J. W. Evans, Bellevue Hill, Sydney, and Mr. J. A. Sutherland, Armidale, N.S.W., were elected Ordinary Members of the Society.

The Chairman announced that the Council had elected the following office-bearers for the 1955–56 session: Vice-Presidents, Mr. D. J. Lee, Mr. A. N. Colefax, Mr. S. J. Copland and Professor J. M. Vincent; Honorary Treasurer, Dr. A. B. Walkom; Honorary Secretaries, Dr. W. R. Browne and Dr. A. B. Walkom.

The Chairman also announced that Mrs. Dorothy A. Thorp, B.Sc. (Lond.), had been elected a member of Council in place of Professor P. D. F. Murray.

Library accessions amounting to 17 volumes, 109 parts or numbers, 2 bulletins, 1 report and 1 pamphlet, total 130, had been received since the last meeting.

The papers taken as read at the March Ordinary Monthly Meeting were discussed.

PAPERS READ.

1. Nitrogen Economy in Semi-arid Plant Communities. Part I. The Environment and General Consideration. By N. C. W. Beadle and Y. T. Tchan.

2. The Petrology of the Northern Part of the Wyangala Bathylith. By N. C. Stevens.

3. Some Notes on the Genus *Polystichum* in South-eastern Australia. By Mary D. Tindale.

4. Studies of Bean Anthracnose in Australia. By W. L. Waterhouse.

NOTES AND EXHIBITS.

Mrs. Pearl R. Messmer exhibited: (1) *Polystichum formosum* Tindale—large plants in cultivation, taken as small seedlings four years ago on Binna Burra Ridge, McPherson Range, S.E. Queensland (altitude approx. 3,000 ft.). In her experience *P. formosum* is very variable, but individual forms, under cultivation, are constant in character, despite variations in conditions and altitude. Sori are always present on all fronds from their very early stages of development. Proliferation was never observed. (2) The new species of *Polystichum*, described by Miss Tindale, from approx. 4,000 ft. altitude, on western slope of Mt. Kaputar, Nandewar Range. This species has been in cultivation for eighteen months, and, at sea level, it is showing variation from the original form,

the segments broadening and coarsening. (3) *Polystichum australiense* Tindale, from Mooney Mooney Creek, near Gosford. Under cultivation during four years the character of this plant has varied greatly from the original appearance. Brought in as a developed plant, the fronds were slender, pinnae slender and widely separated, pinnules rhomboidal, sharply acuminate, obscurely toothed. Under identical conditions it has now developed into a luxuriant, normal form of *P. australiense,* copiously proliferous at apices of fronds, but in four years a single sorus on this plant has never been observed.

Miss M. B. Macdonald exhibited cultures and herbarium specimen of members of the family Characeae of freshwater Algae. The morphology of the plants was briefly discussed, and it was emphasized that their large cells were extremely useful tools in cell-physiology studies. Australia has about 50 species (most of them endemic) of the world total of 292.

Mr. J. McGarity exhibited, by invitation, soil samples and kodachrome slides illustrating the paper by himself and Mr. D. Munns read at the November Ordinary Monthly Meeting on anomalous Krasnozem soils in the Richmond–Tweed region.

Dr. G. D. Osborne exhibited specimens of Lower Carboniferous calcareous mudstone containing numerous examples of the genus *Spirifer* allied to *striatus*, from Bundabah Creek between Karuah and Tea Gardens, Port Stephens district.

ORDINARY MONTHLY MEETING.

25th May, 1955.

Dr. F. V. Mercer, President, in the chair.

Professor R. L. Crocker, University of Sydney, and Mrs. Eva Morgan, Haberfield, N.S.W., were elected Ordinary Members of the Society.

The Chairman offered congratulations to Dr. D. P. Drover on obtaining the degree of Doctor of Philosophy of the University of Western Australia, Dr. N. C. Stevens on obtaining the degree of Doctor of Philosophy of the University of Sydney, and Mrs. Elise E. Tugby on obtaining the degree of M.Sc. of the University of Sydney.

Library accessions amounting to 21 volumes, 77 parts or numbers, and 5 reports, total 103, had been received since the last meeting.

The Chairman drew the attention of members to the three new postcards of the Society's Wildflower Series which are now available at 6d. each (plus postage).

PAPERS READ.

1. Notes on the Australian Rutelinae (Scarabaeidae, Coleoptera): Suppression of a Generic Name under *Clilopocha* Lea. By P. B. Carne.

2. Nitrogen Economy in Semi-arid Plant Communities. Part II. The Non-symbiotic Nitrogen-fixing Organisms. By Y. T. Tchan and N. C. W. Beadle.

3. Inheritance of Reaction to Wheat Stem Rust in Crosses involving Marquillo, Thatcher and Hochzucht. By D. S. Athwal and I. A. Watson.

4. Australian Rust Studies. XIV. Investigations of Rust of Maize caused by *Puccinia sorghi* Schw. By W. L. Waterhouse.

5. A New Species of *Proctotrupes* reared from the Fern Weevil (Hymenoptera, Proctotrupidae). By E. F. Riek.

6. Notes on Australasian Simuliidae (Diptera). IV. By M. J. Mackerras and I. M. Mackerras.

NOTES AND EXHIBITS.

Mr. G. H. Hardy exhibited three specimens of *Rhyphus* from Katoomba—*R. dubius* Macq., *R. funebris* Fuller and *R. neozelandicus* Schin. The two latter are new records for New South Wales. One had two mites (also exhibited) attached to the abdomen.

SYMPOSIUM.

Notes on recent botanical researches in the Kosciusko region were given and illustrated by Mr. Barlow, Mr. Smith-White, Miss Briggs, Dr. Hotchkiss and Miss Macdonald.

ORDINARY MONTHLY MEETING.

29th JUNE, 1955.

Dr. F. V. Mercer, President, in the chair.

Miss Barbara G. Briggs, Roseville, N.S.W., was elected an Ordinary Member of the Society.

The Chairman announced that the Council had elected Dr. Lilian Fraser to be a Vice-President and Mr. A. J. Bearup a member of Council in place of Mr. D. J. Lee.

The Chairman offered congratulations to Rev. H. M. R. Rupp on the award of the Australian Natural History Medallion for 1954.

The Chairman announced that Library Accessions amounting to 22 volumes, 92 parts or numbers, 4 bulletins, 4 reports and 7 pamphlets, total 129, had been received since the last meeting.

PAPERS READ.

1. A New Species of *Echinonyssus* Hirst, 1925, from Queensland (Acarina: Liponyssinae). By Robert Domrow.

2. The Nymph of *Euschöngastia smithi* (Womersley, 1939) (Acarina, Trombiculidae). By Robert Domrow.

3. A New Species of *Cidaphus* Foerster from Australia, with a Note on the Systematic Position of *Tetragonalys pagana* Morley. By A. W. Parrott.

4. Systematic Status of a Leaf Rust on *Hordeum leporinum* Link. in Australia. By E. P. Baker and K. S. McWhirter.

LECTURETTE

A lecturette entitled "Cicadas and their Allies", illustrated by lantern-slides and a gramophone record, was delivered by Dr. J. W. Evans.

ORDINARY MONTHLY MEETING.

27th JULY, 1955.

Dr. F. V. Mercer, President, in the chair.

Mr. Roderick Dobson, Wahroonga, N.S.W., Miss Shirley M. Ryan, Clovelly, N.S.W., and Mr. Richard J. Slack-Smith, Rockdale, N.S.W., were elected Ordinary Members of the Society.

The Chairman offered congratulations to Mr. N. W. G. Macintosh, M.B., B.S., on his appointment to the Challis Chair of Anatomy in the University of Sydney.

The President offered congratulations to Dr. Y. T. Tchan on his appointment as Senior Lecturer in Microbiology at the University of Sydney. The President expressed the Society's satisfaction with the work Dr. Tchan had carried out during his five years as Macleay Bacteriologist to the Society.

The Chairman announced that Library Accessions amounting to 21 volumes, 280 parts or numbers, 53 bulletins, 3 reports and 8 pamphlets, total 364, had been received since the last meeting.

PAPERS READ.

1. New Species of Staphylinidae from Australia. By W. O. Steel. (*Communicated by J. W. T. Armstrong.*)

2. Diseases of Rice in Australia. By P. G. Valder.

3. Estimation of Protozoan Populations in Soils by Direct Microscopy. By J. S. Bunt and Y. T. Tchan.

4. Some Australasian Mosquitoes (Diptera, Culicidae) of the Subgenera *Pseudoskusea* and *Neoculex*. By P. F. Mattingly and Elizabeth N. Marks.

5. The Occurrence of Three New Wheat Stem Rusts in Australia. By I. A. Watson.

6. The Diptera of Katoomba. Part 1. Therevidae. By G. H. Hardy.

EXHIBIT.

Professor R. L. Crocker showed a film of the 1939 Simpson Desert Expedition which was led by the late Dr. C. T. Madigan.

ORDINARY MONTHLY MEETING.

28th September, 1955.

Dr. F. V. Mercer, President, in the chair.

Mr. W. A. Muirhead, B.Sc.Agr., Condobolin, N.S.W., was elected an Ordinary Member of the Society.

The Chairman offered congratulations to Dr. L. B. Barton Browne and Dr. D. F. McMichael on obtaining the degree of Ph.D. of the University of Sydney and Harvard University respectively.

The Chairman announced that the Council is prepared to receive applications for Linnean Macleay Fellowships tenable for one year from 1st January, 1956, from qualified candidates. The range of actual salary is £650–£800, according to qualifications. Applications should be lodged with the Honorary Secretary not later than Wednesday, 2nd November, 1955.

The Chairman announced that Dr. C. E. M. Gunther had donated a valuable collection of reprints on mites to the Society's library; that a copy of the "Proceedings of the UNESCO Symposium on Typhoons, 9–12 November, 1954, Tokyo" (1955) had been presented to the Society by the Japanese National Commission for UNESCO, Tokyo, Japan; and that the following publications had been received from the British Museum (Natural History): "A Systematic Monograph of the Dermaptera of the World based on Material in the British Museum (Natural History), Part 1. Pygidicranidae Subfamily Diplatyinae", by W. D. Hincks, D.Sc. (1955); and "Catalogue of the Type Specimens of Microlepidoptera in the British Museum (Natural History) described by Edward Meyrick", Vols. 1 and 2, by J. F. Gates Clarke (1955).

The Chairman also announced that Library Accessions amounting to 25 volumes, 157 parts or numbers, 19 bulletins, 10 reports and 207 pamphlets (including 166 from Dr. C. E. M. Gunther), total 418, had been received since last meeting.

PAPERS READ.

1. Pleistocene Glaciation in the Victorian Alps. By Stella G. M. Carr and A. B. Costin.

2. Notes on Australian Fur-mites (Listrophoridae, Atopomelinae), with Description of a New Genus. By Robert Domrow.

3. Acarina from Five Hundred Native Mammals from Queensland. By Robert Domrow and D. J. W. Smith.

4. A New Genus and Two New Species of Acarina from Northern Australia. By H. Womersley.

5. New Species of Termites from Australia. By F. J. Gay. (*Communicated by K. L. Taylor.*)

LECTURETTE.

A lecturette on "The Differentiation of Secondary Cartilage" was delivered by Professor P. D. F. Murray.

ORDINARY MONTHLY MEETING.

26th October, 1955.

Dr. F. V. Mercer, President, in the chair.

The Chairman referred to the death on 5th October, 1955, of Dr. G. D. Osborne, who had been a member of the Society since 1921, a member of Council since 1942, and President, 1947–48.

Mr. A. E. Jobson, East Lindfield, N.S.W., and Dr. N. G. Stephenson, Sydney University, were elected Ordinary Members of the Society.

The Chairman offered congratulations to Dr. J. A. Keast on obtaining the degree of Ph.D., of Harvard University.

The Chairman announced that the Council is prepared to receive applications for Linnean Macleay Fellowships tenable for one year from 1st January, 1956, from qualified

candidates. The range of actual salary is £650–£800, according to qualifications. Applications should be lodged with the Hon. Secretary not later than Wednesday, 2nd November, 1955.

The Chairman announced that Library Accessions amounting to 22 volumes, 102 parts or numbers, 2 bulletins and 1 report, total 127, had been received since last meeting.

PAPERS READ.

1. Robert Brown's Australian Collecting Localities. By Miss N. T. Burbidge. (*Communicated by Miss Joyce W. Vickery.*)

2. New information on the Corroboree Frog (*Pseudophryne corroboree* Moore). By A. N. Colefax.

3. The Genera *Campylochirus* Trouessart and *Austrochirus* Womersley in Australia (Acarina, Listrophoridae). By Robert Domrow.

4. Physiologic Specialization in Crown Rust of Oats. By E. P. Baker and Y. M. Upadhyaya.

NOTES AND EXHIBITS.

Mr. A. N. Colefax exhibited two live specimens of the Corroboree Frog, illustrating his paper. These specimens are the original ones collected at Island Bend on the Snowy River, N.S.W., in January, 1954. Live specimens of *Pseudophryne australis*, from Hazelbrook in the Blue Mountains, N.S.W., were also exhibited.

Dr. F. V. Mercer exhibited a specimen of *Stylidium* (the Trigger Plant). The style-anthers are present on a single structure which is sensitive to touch. Such behaviour is extremely rare in plants and in this species forms an effective pollination mechanism. Dr. Mercer also exhibited a technique for isolating single protoplasts and vacuoles from plant tissue, illustrated by Kodachrome slides.

ORDINARY MONTHLY MEETING.

30th NOVEMBER, 1955.

Dr. F. V. Mercer, President, in the chair.

Messrs. B. A. Barlow, B.Sc., Sydney University; K. D. Fairey, Box 1176, G.P.O., Sydney; J. W. McGarity, B.Sc.Agr., Sydney University, and Mrs. Clare A. Rae, B.Sc., Armidale, N.S.W., were elected Ordinary Members of the Society.

The Chairman offered congratulations to Associate Professor J. M. Vincent on obtaining the degree of D.Sc.Agr. for his research into the "Root Nodule Bacteria of Pasture Legumes".

The Chairman announced that Dr. J. W. Evans had been elected a member of the Council, to fill the vacancy caused by the death of Dr. G. D. Osborne.

The Chairman announced that Miss Nola J. Hannon, B.Sc., and Miss Mary B. Macdonald, B.Sc., had been re-appointed to Linnean Macleay Fellowships in Botany for one year from 1st January, 1956.

The Chairman announced that Library Accessions amounting to 17 volumes, 135 parts or numbers, 12 bulletins, 6 reports and 7 pamphlets, total 177, had been received since last meeting.

PAPERS READ.

1. A New Chromosome Form of *Casuarina suberosa*. By B. Barlow. (*Communicated by Dr. F. V. Mercer.*)

2. Some Examples of Stream-derangement in the Kosciusko Area. By W. R. Browne, D.Sc., T. G. Vallance, B.Sc., Ph.D., and the late Harold Rutledge, Ph.D.

3. An Estipulodic Form of *Chara australis* R.Br. (= *Protochara australis* Woms. and Ophel). By Mary B. Macdonald and A. T. Hotchkiss.

4. The Australasian Diptera of J. R. Malloch. By David J. Lee, Mabel Crust and C. W. Sabrosky.

LECTURETTE.

A lecturette entitled "Dr. James Stuart: Artist-Naturalist" was given by Messrs. A. Musgrave and G. P. Whitley.

LIST OF MEMBERS.

(15th December, 1955.)

ORDINARY MEMBERS.

(An asterisk (*) denotes Life Member.)

1940 Abbie, Professor Andrew Arthur, M.D., B.S., B.Sc., Ph.D., c.o. University of Adelaide, Adelaide, South Australia.
1927 *Albert, Michel Francois, "Boomerang", 42 Billyard Avenue, Elizabeth Bay, Sydney.
1940 *Allman, Stuart Leo, B.Sc.Agr., M.Sc., Entomological Branch, Department of Agriculture, Farrer Place, Sydney.
1922 Anderson, Robert Henry, B.Sc.Agr., Botanic Gardens, Sydney.
1927 *Armstrong, Jack Walter Trench, "Callubri", Nyngan, N.S.W.
1952 Ashton, David Hungerford, B.Sc., 92 Warrigal Road, Surrey Hills, E.10, Victoria.
1912 Aurousseau, Marcel, B.Sc., No. 15 Hollycroft Avenue, London, N.W.3, England.

1952 Baas-Becking, L. G. M., Ph.D., D.Sc., C.S.I.R.O., Division of Fisheries, P.O. Box 21, Cronulla, N.S.W.
1951 Backhouse, Thomas Clive, M.B., B.S., D.P.H., D.T.M. & H., F.R.A.C.P., School of Public Health and Tropical Medicine, Sydney University.
1952 Baehni, Professor Charles, Dr.sc., Conservatoire botanique, Université de Genève, 192, rue de Lausanne, Genève, Switzerland.
1949 Baker, Eldred Percy, B.Sc.Agr., Ph.D., Faculty of Agriculture, Sydney University.
1950 *Barber, Professor Horace Newton, M.A., Ph.D., Department of Botany, University of Tasmania, Hobart, Tasmania.
1955 Barlow, Bryan Alwyn, B.Sc., Department of Botany, Sydney University.
1954 Baur, George Norton, B.Sc.Agr., Dip.For., c.o. Forest Office, Coff's Harbour Jetty, N.S.W.
1935 *Beadle, Professor Noel Charles William, D.Sc., University of New England, Armidale, 5N, N.S.W.
1946 Bearup, Arthur Joseph, 66 Pacific Avenue, Penshurst, N.S.W.
1940 Beattie, Joan Marion, D.Sc. (*née* Crockford), c.o. Radium Hill Project, Radium Hill, South Australia.
1952 Bennett, Miss Isobel Ida, Department of Zoology, Sydney University.
1907 Benson, Professor William Noel, B.A., D.Sc., F.G.S., University of Otago, Dunedin, New Zealand.
1948 Besly, Miss Mary Ann Catherine, B.A., 7 Myra Street, Wahroonga, N.S.W.
1954 Black, Roger Foster, B.Sc., Department of Botany, Sydney University.
1941 Blake, Stanley Thatcher, M.Sc., Botanic Gardens, Brisbane, Queensland.
1929 Boardman, William, M.Sc., Zoology Department, University of Melbourne, Carlton, N.3, Victoria.
1946 Brett, Robert Gordon Lindsay, B.Sc., 7 Petty Street, West Hobart, Tasmania.
1955 Briggs, Miss Barbara Gillian, 13 Findlay Avenue, Roseville, N.S.W.
1924 Browne, Ida Alison, D.Sc. (*née* Brown), Department of Geology, Sydney University.
1949 Browne, Lindsay Blakeston Barton, Ph.D., C.S.I.R.O. Division of Entomology, P.O. Box 109, City, Canberra, A.C.T.
1911 Browne, William Rowan, D.Sc., Department of Geology, Sydney University.
1952 Bunt, John Stuart, B.Sc.Agr., Antarctic Division, 187 Collins Street, Melbourne, Victoria.
1949 Burden, John Henry, 1 Havilah Street, Chatswood, N.S.W.
1931 *Burges, Professor Norman Alan, M.Sc., Ph.D., Professor of Botany, University of Liverpool, Liverpool, England.
1920 Burkitt, Professor Arthur Neville St. George Handcock, M.B., B.Sc., Medical School, Sydney University.

1955 Cameron, Miss Beryl Marlene, B.Sc., Department of Zoology, Sydney University.
1927 Campbell, Thomas Graham, Division of Economic Entomology, C.S.I.R.O., P.O. Box 109, City, Canberra, A.C.T.
1934 *Carey, Professor Samuel Warren, D.Sc., Geology Department, University of Tasmania, Hobart, Tasmania.
1949 Carne, Phillip Broughton, B.Agr.Sci. (Melb.), Ph.D. (London), D.I.C., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T.
1936 *Chadwick, Clarence Earl, B.Sc., Entomological Branch, Department of Agriculture, Farrer Place, Sydney.
1947 Christian, Stanley Hinton, Malaria Control, Department of Public Health, Banz, Western Highlands, via Lae, New Guinea.

1932 *Churchward, John Gordon, B.Sc.Agr., Ph.D., 1 Hunter Street, Woolwich, N.S.W.
1946 Clark, Laurance Ross, M.Sc., c.o. C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T.
1947 Clarke, Mrs. Muriel Catherine, M.Sc (*née* Morris), 122 Swan Street, Morpeth, N.S.W.
1901 Cleland, Professor John Burton, M.D., Ch.M., 1 Dashwood Road, Beaumont, Adelaide, South Australia.
1931 Colefax, Allen Neville, B.Sc., Department of Zoology, Sydney University.
1946 Colless, Donald Henry, 9 Eng Neo Avenue, Singapore 21, Malaya.
1942 Copland, Stephen John, M.Sc., Chilton Parade, Warrawee, N.S.W.
1947 Costin, Alec Baillie, B.Sc.Agr., Island Bend, via Cooma, 4S, N.S.W.
1908 Cotton, Professor Leo Arthur, M.A., D.Sc., 113 Queen's Parade East, Newport Beach, N.S.W.
1950 Crawford, Lindsay Dinham, B.Sc., 4 Dalton Avenue, West Hobart, Tasmania.
1955 Crocker, Professor Robert Langdon, D.Sc., Department of Botany, Sydney University.

1945 Davis, Mrs. Gwenda Louise, Ph.D., B.Sc., Faculty of Science, The University of New England, Armidale 5N, N.S.W.
1934 Day, William Eric, 23 Gelling Avenue, Strathfield, N.S.W.
1937 Deuquet, Camille, B.Com., 126 Hurstville Road, Oatley, N.S.W.
1953 Dobrotworsky, Nikolai V., M.Sc., Department of Zoology, University of Melbourne, Carlton, N.3, Victoria.
1955 Dobson, Roderick, 19 Lucinda Avenue, Wahroonga, N.S.W.
1954 Domrow, Robert, B.Sc., Queensland Institute of Medical Research, Herston Road, Herston N9, Brisbane, Queensland.
1954 Douglas, Geoffrey William, B.Agr.Sci., C.S.I.R.O., Box 143, Albury, N.S.W.
1948 Drover, Donald P., Institute of Agriculture, University of Western Australia, Nedlands, W.A.
1946 Durie, Peter Harold, M.Sc., C.S.I.R.O., Veterinary Parasitology Laboratory, Yeerongpilly, Brisbane, Queensland.
1952 Dyce, Alan Lindsay, B.Sc.Agr., C.S.I.R.O., Division of Entomology, P.O. Box 109, City, Canberra, A.C.T.

1948 Ealey, Eric H. M., M.Sc., Girrawheen, Duffy Avenue, Thornleigh, N.S.W.
1953 Edwards, Dare William, B.Sc.Agr. (Hons.), Forestry Commission of N.S.W., Division of Wood Technology, 96 Harrington Street, Sydney.
1949 Elliott, John Henry, "Greengates", Pennant Hills Road, Beecroft, N.S.W.
1947 Endean, Robert, M.Sc., Department of Zoology, University of Queensland, Brisbane, Queensland.
1930 English, Miss Kathleen Mary Isabel, B.Sc., 2 Shirley Road, Roseville, N.S.W.
1953 Errey, Mrs. Beatrice Mary, M.Sc., P.O., Forestville, via Chatswood, N.S.W.
1955 Evans, John William, M.A., D.Sc., Sc.D., 47 Bundarra Road, Bellevue Hill, N.S.W.

1955 Fairey, Kenneth David, Box 1176, G.P.O., Sydney.
1953 Frame, William Robert, Goroka, New Guinea.
1948 Fraser, Ian McLennan, Ph.D. (Cambridge), School of Medicine, College of Medical Evangelists, Loma Linda, California, U.S.A.
1930 Fraser, Miss Lilian Ross, D.Sc., "Hopetoun", 25 Bellamy Street, Pennant Hills, N.S.W.

1950 Garden, Miss Joy Gardiner, B.Sc.Agr., Botanic Gardens, Sydney.
1935 *Garretty, Michael Duhan, D.Sc., "Surrey Lodge", Mitcham Road, Mitcham, Victoria.
1944 Greenwood, William Frederick Neville, 11 Wentworth Avenue, Waitara, N.S.W.
1946 *Griffiths, Mrs. Mabel, B.Sc. (*née* Crust), 2 Carden Avenue, Wahroonga, N.S.W.
1936 Griffiths, Mervyn Edward, M.Sc., Australian Institute of Anatomy, Canberra, A.C.T.
1939 *Gunther, Carl Ernest Mitchelmore, M.B., B.S., D.T.M., D.T.M. & H. (England), 96 Woodland Street, Balgowlah, N.S.W.

1928 Hamilton, Edgar Alexander, 16 Hercules Street, Chatswood, N.S.W.
1952 Hannon, Miss Nola Jean, B.Sc., 22 Leeder Avenue, Penshurst, N.S.W.
1952 *Hansford, Clifford Gerald, M.A., Sc.D. (Cantab.), D.Sc. (Adel.), F.L.S., Waite Agricultural Research Institute, Private Bag, G.P.O., Adelaide, South Australia.
1917 Hardy, George Huddleston Hurlstone, "Karambi", Letitia Street, Katoomba, N.S.W.
1951 Hewitt, Bernard Robert, 4 Hillview Street, Lakemba, N.S.W.
1930 Heydon, George Aloysius Makinson, M.B., Ch.M., Flat 5, 79 O'Sullivan Road, Rose Bay, N.S.W.
1938 Hill, Miss Dorothy, M.Sc., Ph.D., Department of Geology, University of Queensland, Brisbane, Queensland.
1943 *Hindmarsh, Miss Mary Maclean, B.Sc., Ph.D., 79 Onslow Street, Rose Bay, N.S.W.

1930 Holmes, Professor James Macdonald, Ph.D., B.Sc., F.R.G.S., F.R.S.G.S., Department of Geography, Sydney University.
1943 Horowitz, Benzoin, Eng.Agr.S., Dr.Agr.Sc. (Cracow, Poland), C.S.I.R.O., c.o. Waite Institute, Private Mail Bag, Adelaide, South Australia.
1932 Hossfeld, Paul Samuel, M.Sc., 132 Fisher Street, Fullarton, South Australia.
1953 *Hotchkiss, Arland Tillotson, M.S., Ph.D. (Cornell), Department of Biology, University of Louisville, Louisville 8, Kentucky, U.S.A.
1942 Humphrey, George Frederick, M.Sc., Ph.D., C.S.I.R.O. Marine Biological Laboratory, Box 21, Cronulla, N.S.W.

1938 Jacobs, Maxwell Ralph, D.Ing., M.Sc., Dip.For., Australian Forestry School, Canberra, A.C.T.
1952 Jessup, Rupert William, M.Sc., c.o. 4 Marion Street, West Croydon, South Australia.
1947 Johnson, Lawrence Alexander Sidney, B.Sc., c.o. National Herbarium, Botanic Gardens, Sydney.
1945 Johnston, Arthur Nelson, B.Sc.Agr., 99 Newton Road, Strathfield, N.S.W.
1937 Jones, Mrs. Valerie Margaret Beresford, M.Sc. (*née* May), Mooloolabel Esplanade, Narrabeen, N.S.W.
1930 Joplin, Miss Germaine Anne, B.A., Ph.D., D.Sc., Department of Geophysics, Australian National University, Canberra, A.C.T.

1949 Keast, James Allen, M.Sc., M.A., Ph.D. (Harvard), Australian Museum, College Street, Sydney.
1951 Kerr, Harland Benson, B.Sc.Agr., 41 Badminton Road, Croydon, N.S.W.
1937 Kesteven, Geoffrey Leighton, D.Sc., c.o. F.A.O. of United Nations, Viale delle Terme di Caracalla, Rome, Italy.
1938 Kesteven, Hereward Leighton, D.Sc., M.D., Maroochydore, Queensland.
1938 Kinghorn, James Roy, C.M.Z.S., Australian Museum, College Street, Sydney.

1939 Langford-Smith, Trevor, M.Sc., School of Pacific Studies, Australian National University, Canberra, A.C.T.
1952 Latter, Barrie Dale Hingston, B.Sc.Agr., 25 Abbott Street, Coogee, N.S.W.
1946 *Lawrence, James Joscelyn, B.Sc., School of Public Health and Tropical Medicine, Sydney University.
1932 Lawson, Albert Augustus, 9 Wilmot Street, Sydney.
1934 Lee, Mrs. Alma Theodora, M.Sc. (*née* Melvaine), Manor Road, Hornsby, N.S.W.
1936 Lee, David Joseph, B.Sc., School of Public Health and Tropical Medicine, Sydney University.
1943 Lothian, Thomas Robert Noel, Botanic Gardens, Adelaide, South Australia.
1949 Lower, Harold Farnham, Waite Agricultural Research Institute, University of Adelaide, Private Mail Bag, G.P.O., Adelaide, South Australia.
1951 Lowery, Edwin Sanders, M.A., R.M.B. 4, Windsor Road, Baulkham Hills, N.S.W.

1951 Macdonald, Colin Lewis, 372 Wilson Street, Albury East, N.S.W.
1954 Macdonald, Miss Mary Beth, B.Sc., Department of Botany, Sydney University.
1948 Macintosh, Professor Neil William George, M.B., B.S., 32 Benelong Crescent, Bellevue Hill, N.S.W.
1922 Mackerras, Ian Murray, M.B., Ch.M., B.Sc., Queensland Institute of Medical Research, Herston Road, Herston N9, Brisbane, Queensland.
1931 *Mair, Herbert Knowles Charles, B.Sc., Botanic Gardens, Sydney.
1948 Marks, Miss Elizabeth Nesta, M.Sc., Ph.D., Department of Entomology, University of Queensland, Brisbane, Queensland.
1953 Martin, Mrs. Hilda Ruth Brownell, B.Sc. (*née* Simons), 36 Spencer Road, Killara, N.S.W.
1905 Mawson, Sir Douglas, D.Sc., B.E., F.R.S., University of Adelaide, Adelaide, South Australia.
1933 Maze, Wilson Harold, M.Sc., University of Sydney.
1951 McAlpine, David Kendray, 12 St. Thomas Street, Bronte, N.S.W.
1932 McCulloch, Robert Nicholson, D.Sc.Agr., B.Sc., Roseworthy Agricultural College, Roseworthy, South Australia.
1954 McDonald, Miss Patricia M., B.Sc., Dip.Ed., 29 Dee Why Parade, Dee Why, N.S.W.
1948 McKee, Hugh Shaw, B.A., D.Phil. (Oxon.), South Pacific Commission, P.O. Box 9, Noumea, New Caledonia.
1952 McMichael, Donald Fred, B.Sc., Ph.D. (Harvard), Australian Museum, College Street, Sydney.
1947 McMillan, Bruce, M.B., B.S., c.o. Medical Headquarters, Kaduna, Northern Nigeria.
1944 Mercer, Frank Verdun, B.Sc., Ph.D. (Cambridge), Botany School, Sydney University.
1948 Mercer, Mrs. Greta, B.A., B.Sc. (*née* Baddams), 13 Hampton Road, Keswick, South Australia.
1947 Messmer, Mrs. Pearl Ray, 64 Treatts Road, Lindfield, N.S.W.

1952 *Meyer, George Rex, B.Sc., Dip.Ed., Department of Zoology, Sydney University.
1949 *Miller, Allen Horace, B.Sc., Dip.Ed., 46a Wentworth Street, Wallsend 2N, N.S.W.
1938 Miller, David, Ph.D., M.Sc., F.R.S.N.Z., F.R.E.S., Cawthron Institute, Nelson, New Zealand.
1948 Millerd, Miss Alison Adele, M.Sc., Ph.D., Department of Biochemistry, Sydney University.
1947 Millett, Mervyn Richard Oke, B.A., 18 Albion Road, Box Hill, E11, Victoria.
1949 Minter, Philip Clayton, 49 Cotswold Road, Strathfield, N.S.W.
1955 Morgan, Mrs. Eva, B.Sc., 178 Homebush Road, Strathfield, N.S.W.
1944 Moye, Daniel George, B.Sc., Dip.Ed., 6 Kaling Place, Cooma, N.S.W.
1939 Moye, Mrs. Joan, B.Sc. (*née* Johnston), 6 Kaling Place, Cooma, N.S.W.
1955 Muirhead, Warren Alexander, B.Sc.Agr., Soil Conservation Service, Box 11, Condobolin 7W, N.S.W.
1926 Mungomery, Reginald William, c.o. Bureau of Sugar Experiment Stations, Department of Agriculture and Stock, Brisbane, B.7, Queensland.
1949 Murray, Professor Patrick Desmond Fitzgerald, M.A., D.Sc., Department of Zoology, University of Sydney, N.S.W.
1920 Musgrave, Anthony, F.R.E.S., Australian Museum, College Street, Sydney.
1949 Myers, Kenneth, C.S.I.R.O., Wildlife Survey Section, Field Station, 598 Affleck Street, Albury, N.S.W.

1947 Nashar, Mrs. Beryl, B.Sc., Ph.D., Dip.Ed. (*née* Scott), c/- 23 Morris Street, Mayfield West 2N, N.S.W.
1925 Newman, Ivor Vickery, M.Sc., Ph.D., F.R.M.S., F.L.S., 1 Stuart Street, Wahroonga, N.S.W.
1922 Nicholson, Alexander John, D.Sc., F.R.E.S., C.S.I.R.O., Box 109, Canberra, A.C.T.
1935 *Noble, Norman Scott, D.Sc.Agr., M.Sc., D.I.C., C.S.I.R.O., 314 Albert Street, East Melbourne, C.2, Victoria.
1920 Noble, Robert Jackson, B.Sc.Agr., Ph.D., 32A Middle Harbour Road, Lindfield, N.S.W.
1912 North, David Sutherland, 42 Chelmsford Avenue, Lindfield, N.S.W.

1948 O'Farrell, Professor Antony Frederick Louis, A.R.C.Sc., B.Sc., F.R.E.S., Department of Zoology, University of New England, Armidale 5N, N.S.W.
1950 O'Gower, Alan Kenneth, M.Sc., 21 Gaerloch Avenue, South Bondi, N.S.W.
1927 Oke, Charles George, 34 Bourke Street, Melbourne, C.1, Victoria.
1927 Osborn, Professor Theodore George Bentley, D.Sc., F.L.S., 22 Hardwicke Street, Balwyn E8, Victoria.
1950 Oxenford, Reginald Augustus, B.Sc., 10 Fry Street, Grafton 3C, N.S.W.

1952 Packham, Gordon Howard, 61 Earlwood Avenue, Earlwood, N.S.W.
1952 Palmer, Rev. Robert George, Methodist Parsonage, Dorrigo, N.S.W.
1954 Parrott, Arthur Wilson, "Lochiel", Wakapuaka Road, Hira, R.D., Nelson, New Zealand.
1940 *Pasfield, Gordon, B.Sc.Agr., 20 Cooper Street, Strathfield, N.S.W.
1922 Perkins, Frederick Athol, B.Sc.Agr., Department of Entomology, University of Queensland, Brisbane, Queensland.
1947 Phillips, Miss Marie Elizabeth, M.Sc., Ph.D., Soil Conservation Section, Snowy Mountains Authority, Cooma, N.S.W.
1937 Plomley, Kenneth Francis, c.o. Division of Forest Products, C.S.I.R.O., 69 Yarra Bank Road, South Melbourne, S.E.1, Victoria.
1935 Pope, Miss Elizabeth Carington, M.Sc., C.M.Z.S., Australian Museum, College Street, Sydney.
1938 Pryor, Lindsay Dixon, M.Sc., Dip.For., Parks and Gardens Section, Department of the Interior, Canberra, A.C.T.
1949 Purchase, Miss Hilary Frances, B.Sc.Agr., 19 Hampden Avenue, Cremorne, N.S.W.

1929 Raggatt, Harold George, C.B.E., D.Sc., 60 Arthur Circle, Forrest, Canberra, A.C.T.
1951 Ralph, Bernhard John Frederick, B.Sc., Ph.D. (Liverpool), A.A.C.I., N.S.W. University of Technology, Broadway, Sydney.
1952 Ramsay, Mrs. Helen Patricia, M.Sc. (*née* Lancaster), Cnr. Ridge and Sofala Streets, Portland 6W, N.S.W.
1953 Reye, Eric James, M.B., B.S. (Univ. Qld.), c/- C.S.I.R.O., Veterinary Parasitology Laboratory, Fairfield Road, Yeerongpilly, Queensland.
1950 Rickwood, Frank Kenneth, B.Sc., Department of Geology, Sydney University.
1946 Riek, Edgar Frederick, B.Sc., C.S.I.R.O., Division of Economic Entomology, P.O. Box 109, City, Canberra, A.C.T.
1936 Roberts, Noel Lee, 43 Hannah Street, Beecroft, N.S.W.
1932 Robertson, Rutherford Ness, B.Sc., Ph.D., Food Preservation Research Laboratory, C.S.I.R.O., Private Mail Bag, Homebush, N.S.W.
1945 Ross, Donald Ford, c.o. Ross Bros. Pty. Ltd., 545-547 Kent Street, Sydney.
1925 Roughley, Theodore Cleveland, B.Sc., F.R.Z.S., 5 Coolong Road, Vaucluse, N.S.W.
1955 Ryan, Miss Shirley Margaret, 16 Blackwood Avenue, Clovelly, N.S.W.

1932 Salter, Keith Eric Wellesley, B.Sc., Department of Zoology, Sydney University
1919 *Scammell, George Vance, B.Sc., 7 David Street, Clifton Gardens, N.S.W.
1951 Seccombe, Mrs. Lorraine, B.A., 28 Fairweather Street, Bellevue Hill, N.S.W.
1950 *Sharp, Kenneth Raeburn, B.Sc., Eng. Geology, S.M.H.E.A., Cooma, 4S, N.S.W.
1948 Shaw, Miss Dorothy Edith, M.Sc.Agr., Ph.D., Department of Agriculture, Stock and Fisheries, Port Moresby, Papua-New Guinea.
1930 Sherrard, Mrs. Kathleen Margaret, M.Sc., 43 Robertson Road, Centennial Park, Sydney.
1947 Shipp, Erik, 28 Carranga Road, Lane Cove, N.S.W.
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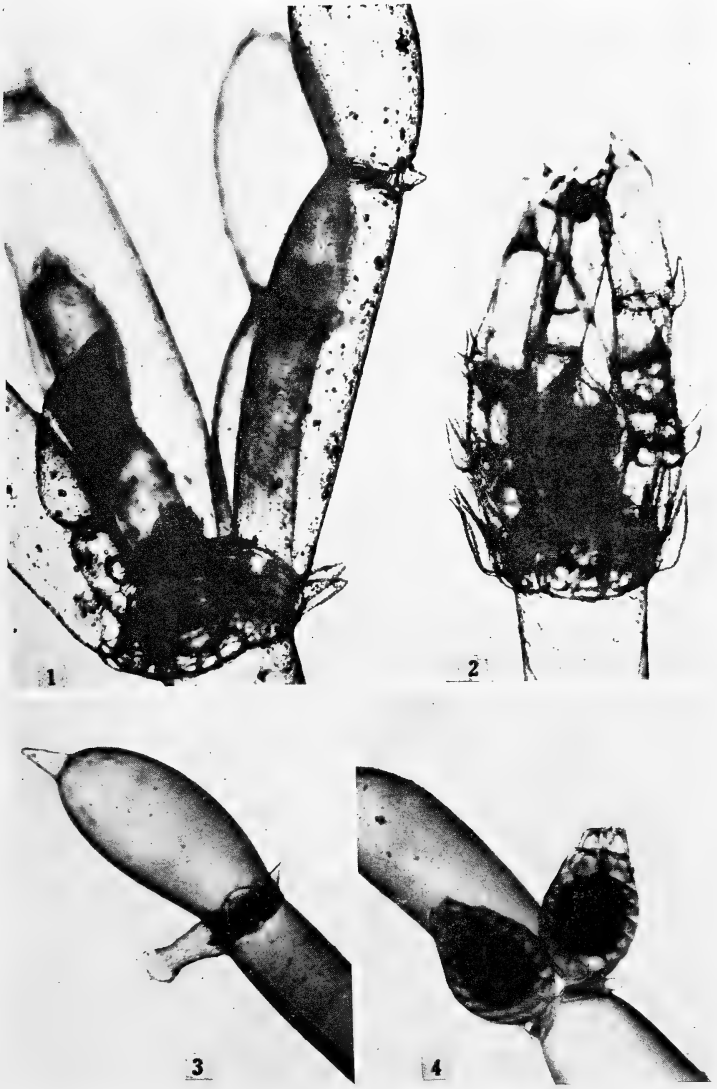
Glaciation in the Victorian Alps.

Chara australis.



Chara australis.

J. R. Malloch