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LINNEAN SOCIETY  
OF  
NEW SOUTH WALES

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FOR THE YEAR

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## ANNUAL GENERAL MEETING.

WEDNESDAY, 29th MARCH, 1944.

The Sixty-ninth Annual General Meeting was held in the Society's Rooms, Science House, Gloucester Street, Sydney, on Wednesday, 29th March, 1944.

Mr. E. Le G. Troughton, C.M.Z.S., F.R.Z.S., President, in the Chair.

The minutes of the preceding Annual General Meeting (31st March, 1943) were read and confirmed.

### PRESIDENTIAL ADDRESS.

In presenting this Report of work begun in the fourth year of the Second World War, I know that members will fully appreciate the manner in which the Society's activities, due largely to the researches of our Macleay Bacteriologist and highly qualified Fellows, have become adjusted to the needs and restrictions of war-time. The resumption of evening meetings, resulting from relaxation of the "black-out" regulations, while reflecting a reassuring general improvement in the immediate war situation, did not result in any noticeable improvement in attendances, although the Council provided interesting addresses when papers were not available. It is, of course, well understood that present conditions inevitably affect the conduct of scientific work, as well as the freedom of members wishing to attend the meetings. It is, however, to be hoped that the coming year may show a marked improvement in attendances, to which end I would suggest that where possible papers be presented in the form of a summary of the research problem, results achieved, and prospects for further research, rather than relying almost entirely on diagrammatic illustration. The presentation of exhibits by members, in which there has been a notable decline, would add a very desirable personal touch to the general interest of the meetings.

Careful supervision has been exercised over the Society's funds and the expenditure in the General Account has been kept within the normal income for the year. The deficit shown in the income of the General Account results from interest overdue in respect of two mortgages, but there is no reason to think that these arrears of interest will not be received. There will be continued necessity for the exercising of strict economy by the Council, as we may expect that there will be a successive loss of income in the near future at each conversion of Commonwealth and other loans in view of the Governmental policy of keeping interest rates down.

The concluding part of Volume lxxviii of the Society's Proceedings was issued in December. The complete volume (254 + xxiv pages, twelve plates, and 110 text-figures) contains twenty-two papers on various branches of Natural History and, in addition, a memorial account of Herbert James Carter. As in the preceding year, so many members were either occupied with special war work or actually in the fighting services, that the number of papers submitted for publication showed a very marked decline and, in consequence, the volume was much smaller than in previous years.

Exchanges from scientific societies and institutions for the session amounted to 878 compared with 1,383, 1,200 and 749 for the three preceding years. During the year the Society has co-operated with the Allied Geographical Section, South-west Pacific Area, in the preparation of an annotated bibliography of all published material in Australia dealing with the South-west Pacific.

Since the last Annual Meeting the names of eight new members have been added to the list and three members have resigned.

Because of ill-health Dr. G. A. Waterhouse did not seek re-election as Honorary Treasurer in April, 1943, and Dr. A. B. Walkom was unanimously elected to fill this position in which Dr. Waterhouse had served the Society for fifteen years during 1926-

1943. Council elected Dr. Waterhouse a Vice-President of the Society for the 1943-1944 session. After over thirty years' service, Dr. G. A. Waterhouse resigned from membership of the Council in November, 1943, and as an expression of appreciation of his untiring and valuable services to the Society, Council elected him a Corresponding Member.

The vacancies in the Council resulting from the resignations of Professor W. J. Dakin and Dr. G. A. Waterhouse were filled by the election of Mr. A. N. Colefax, B.Sc., and Mr. W. H. Maze, M.Sc., and in December, 1943, Mr. T. C. Roughley, B.Sc., F.R.Z.S., was elected a Vice-President in place of Dr. G. A. Waterhouse.

During the year a committee of the Council was appointed to consider the advisability of approaching the Federal Government concerning the Commonwealth control of flora. In view of the obviously adverse effect upon the flora and fauna your Council also gave its support to other Natural History societies in protest against the Government's proposal to lease the major portion of the Kosciusko National Park area for grazing.

It is a pleasure to be able to announce that, early in the year, the Government of New South Wales passed the "Sir Joseph Banks Memorial Fund Act, 1943" establishing a trust of eight members to make recommendations concerning the utilization of the fund collected many years ago to commemorate the life and work of Sir Joseph Banks. In addition to the Chairman, the trust consists of the Principal Librarian of the Public Library and representatives of the following: the Naturalists' Society, the Royal Zoological Society, the Royal Australian Historical Society, the Linnean Society, the Trustees of Captain Cook's Landing Place, and the Minister of Agriculture and Forests. The Secretary, Dr. N. S. Noble, represented this Society at a number of meetings of the Trust, and a report prepared for the State Government late in 1943 sets out a series of recommendations regarding the disposal of the fund.

During the year your Council also elected Archdeacon F. E. Haviland a Corresponding Member of the Society in appreciation of his botanical contributions.

We offer congratulations to Dr. G. A. Waterhouse on being elected a Special Life Fellow of the Royal Entomological Society of London, to Dr. W. L. Waterhouse on his award of the Clarke Memorial Medal by the Royal Society of New South Wales, to Mr. E. Cheel on his award of the Medal of the Royal Society of New South Wales, and to Dr. H. F. Consett Davis on attaining the degree of Doctor of Science of the University of Sydney.

Mr. R. C. Betty, B.Sc., who had been assistant to the Macleay Bacteriologist from 1st February, 1941, resigned on 31st May, 1943, and Mrs. Dorothy M. Frith, B.Sc.Agr. (*née* Killeen), who was selected by your Council to take his place, took up her duties on 1st July, 1943.

In 1939, when Dr. Jensen proposed to initiate a programme of research into nitrogen-fixing bacteria in our soils, four banking institutions provided sufficient funds for the erection of a plant house within the grounds of the University of Sydney and for the employment of an assistant to the Bacteriologist for a period of more than three years. Though Dr. Jensen had made considerable progress in his investigations on soil fertility it was felt that further extensive research in this field would prove of great value. Late in 1943, therefore, as the funds available for payment of an assistant were almost exhausted, the Executive approached the Commonwealth Bank of Australia, the Rural Bank of New South Wales, the Commercial Banking Company of Sydney, Ltd., and the Bank of New South Wales and I am pleased to say that all of the banks concerned have again provided such generous financial support that the salary of an assistant to the Macleay Bacteriologist is assured for at least a further three years.

The year's work of the Society's research staff may be summarized thus:

Dr. H. L. Jensen, Macleay Bacteriologist to the Society, has continued his work on symbiotic nitrogen fixation in pasture legumes. Molybdenum has been found to have a stronger stimulating effect on nitrogen fixation in lucerne than on the uptake of combined nitrogen. Experiments on the influence of soil reaction on nitrogen fixation have shown that the number of root nodules is lower, but the weight of nodules in proportion to the total plant is generally higher, at acid, than at alkaline or neutral,

reaction. The nitrogen-fixing efficiency of the nodules, expressed as gain of nitrogen per unit weight of nodule-substance, decreases at acid reaction in both *Medicago* and *Trifolium*, but the actual gains of nitrogen may, especially in the latter, remain unaltered within wide limits. Molybdenum deficiency has an effect on the efficiency of the nodules similar to that of acid reaction. Two papers on these problems have been published in these PROCEEDINGS. As in the previous year, Dr. Jensen has undertaken the investigation of a number of war-time problems and has achieved further results of considerable value. Since June, 1943, when your Council approved of his name being placed on a special panel for this purpose, his investigations for the army on the deterioration and preservation of military equipment due to mould growth under tropical conditions have been undertaken through the intermediary of the Scientific Liaison Bureau. The checking of sterility of dried blood serum has been continued and the antiseptic effect of locally manufactured drugs has been tested. Dr. Jensen also published a note in *The Medical Journal of Australia* on the preservation of blood for transfusion purposes, and the method recommended has been accepted by the Blood Transfusion Service. As in the previous year, in the absence of the regular lecturer, Dr. Jensen delivered the course in Agricultural Bacteriology at the University of Sydney.

During the first half of the year Mr. J. A. Dulhunty, Linnean Macleay Fellow of the Society in Geology, concluded his research on the classification and origin of the New South Wales torbanites. Later in the year two papers dealing with the results were submitted for publication and already one of these has been published in these PROCEEDINGS. As Mr. Dulhunty had completed his researches on torbanites earlier than had been anticipated your Council gave approval for the commencement of research on the New South Wales coals. The coal problems are closely allied to those of the torbanite deposits, and involve the application of experience and technique gained during the study of torbanites. The problems on which work was carried out during the latter part of the year were the determination of microspore assemblages with the object of correlating seams, and the study of field evidence bearing on environmental conditions of coal formation.

During the first part of the year Dr. Germaine A. Joplin, Linnean Macleay Fellow of the Society in Geology, in continuation of her study of the Ordovician of New South Wales worked on material collected north of Cooma in the vicinity of Murrumbucka, Bunyan and Bredbo. In a paper dealing with this area, published in these PROCEEDINGS later in the year, an attempt was made to interpret the structure, sequence and tectonic history of the Ordovician rocks in the whole of the Cooma region. During a trip early in the year reconnaissance work was undertaken at Albury, and on a later trip some detailed mapping was carried out. This study is still in its initial stages, but so far results show very marked similarities between the Ordovician rocks of this area and those of Cooma. Nevertheless, there are indications of interesting differences between the Cooma and Albury Complexes that may prove slight differences in the sequence of tectonic events, or differences in the erosion level of the two metamorphic complexes.

Miss Frances M. V. Hackney, Linnean Macleay Fellow of the Society in Plant Physiology, continued experiments with mature Granny Smith and Delicious apples after various periods of cool storage. In the early samples of Granny Smith apples the respiration rate generally rose soon after removal from store, and fell subsequently. The resistance of the skin to gaseous diffusion rose and the internal concentration of oxygen fell. In later samples the respiration rate did not rise and the resistance of the skin to the diffusion of oxygen increased. The internal oxygen concentration was initially low and showed little change subsequently. Throughout the year the respiratory quotient was approximately 1.0. In early samples of mature Granny Smith apples the respiration rate increased greatly in an atmosphere of pure oxygen, but in later samples this effect was much less marked. Oxygen supply was probably limiting respiration rate in the early samples. In immature Granny Smith apples, where the resistance to oxygen was low, increased oxygen supply had no effect on respiration. The respiratory behaviour of Delicious apples differed from that of Granny Smith apples, the marked changes which occurred in resistance of the skin in the latter variety not being generally observed in Delicious apples.

Miss Joan M. Crockford, Linnean Macleay Fellow of the Society in Palaeontology, carried out research on Palaeozoic Bryozoa, dealing principally with Permian faunas, especially those of Western Australia and the Northern Territory. This work has included a re-examination of the type specimens of species previously described from these areas, and the revision of species previously described from the Northern Territory has been published in these PROCEEDINGS. In addition, work was commenced on the description of the new species which form the most abundant part of the Western Australian Permian faunas. A paper dealing with the occurrence of Bryozoa in the Ordovician of Central Australia has also been published in these PROCEEDINGS. Miss Crockford is preparing for publication a general review of the development of Bryozoa in the Palaeozoic of Australia, to indicate the degree of development of these faunas in rocks of different age, the assemblages of family and generic groups present in different formations, and to discuss the distribution of species so far described and, where possible, the affinities of the faunas.

There were no additional applications for Linnean Macleay Fellowships in response to the Council's invitation of 22nd September, 1943, and I have pleasure in reminding you that the Council reappointed Mr. J. A. Dulhunty, Dr. Germaine A. Joplin, Miss Frances M. V. Hackney and Miss Joan M. Crockford to Fellowships in Geology, Geology, Plant Physiology and Palaeontology respectively for one year from 1st March, 1944.

During the coming year Mr. J. A. Dulhunty proposes to continue his research on coal, including a study of conditions of coal-measure sedimentation in the various regions of Kamilaroi deposition, in an attempt to establish specific environmental conditions characteristic of the different coal-measures and coal-bearing horizons. He will also study spore assemblages and other microscopical features on different coal-bearing horizons with the object of correlating coal seams. Mr. Dulhunty will also undertake a statistical examination of all available analytical and physical data concerning the Kamilaroi coals.

Dr. Germaine Joplin will continue her study of the belt of metamorphic rocks extending from Albury to Condobolin and hopes to compare and correlate this belt of rocks with the belt passing through Cooma. The ultimate purpose of the work is to investigate the igneous and metamorphic geology of these two belts with a view to interpreting the tectonic history of the Ordovician of New South Wales. During the year Dr. Joplin also hopes to continue her observations on the nature and deposition of the Upper Ordovician slates.

Miss Frances Hackney proposes to continue her investigations on the metabolism of Granny Smith apples. The respiratory behaviour of whole apples, and of slices of apples, which have undergone various periods of cool storage will be investigated with a view to obtaining information on the part played by changes in the resistance of the skin in limiting the respiration rate of the tissue. An attempt will also be made to obtain further information on the nature of the respiratory metabolism by studying the effects of various substances which might accelerate or inhibit the respiration of slices of tissue.

Miss Joan Crockford proposes to continue her researches on the development and distribution of Australian Palaeozoic Bryozoa, with particular reference to the distribution of the Permian faunas.

We wish them success in their coming year's work.

#### THE IMPERATIVE NEED FOR FEDERAL CONTROL OF POST-WAR PROTECTION OF NATURE.

The origin, radiation, and rapid decline of the Australian fauna may be divided into three remarkably unequal periods. Firstly, those ages prior to man's advent, when great climatic and geological changes failed to check the rich radiation of marsupial life. Secondly, that long period of aboriginal occupation during which the biological balance remained fairly static, despite introduction of the first placental carnivore, the cunning dingo or wild dog. Thirdly, in violent contrast, we have the relatively infinitesimal period of white settlement, with its drastic disturbance of natural balance arising from

the inevitable sequence of clearing for crops and stock, ordeal by fire, poison, gun, and snare, and incredible importations such as the rabbit and fox.

Aborigines, because of their inability to cultivate and form settled colonies, wrought little faunal change, while the main effect of the dingo's introduction was apparently to banish its largest carnivorous rival, the thylacine or "pouched-wolf", from the mainland. It is indeed an irony of natural law, not without tragic human parallel in the present phase of human history, that the prolonged security of geological isolation, which encouraged the remarkably varied evolution of the marsupials, has left the slow-breeding and highly specialized mammals defenceless against the invasion of settlement, and their introduced enemies.

Almost a century ago that great bird lover, John Gould, shocked by the unrelenting way in which unique marsupials were driven from their native haunts, wrote with remarkable prescience of things to come: "*Shortsighted indeed are the Anglo-Australians, or they would long ere this have made laws for the preservation of their highly singular, and in many instances noble, indigenous animals.*" Though each State of the Commonwealth subsequently provided varying measures of protection, about the time of Federation in 1901, differing views concerning species, and the extent of protection, has militated against the success of laws which have been relaxed all too often for commercial gain.

Evidently Gould visualized, at the time of his far-seeing observations, some form of national control of Australian wild life, the need for which is indeed imperative if much of the remaining fauna is to survive the post-war decade of expansion in such matters as immigration, and irrigation for closer settlement. It is incontestable, therefore, that there was an immediate need for the inclusion of national control of fauna and flora within the Constitutional Amendment proposals for Post-war Reconstruction, not only regarding unified Federal control, but also for the consideration of territorial and international adjustments, such as in the protection of wild life, and exploitation of whales and seals.

#### PROPOSALS FOR A COMMONWEALTH BIOLOGICAL SURVEY.

The paramount need for Commonwealth control of fauna and related problems, self-evident at the time of Federation, has been the subject of several recommendations of the Australian and New Zealand Association for the Advancement of Science, authoritative State reports—and many presidential addresses. Obviously, unification of Federal and States' management of fauna is essentially linked with the foundation of some co-ordinating agency of investigation and control, such as the United States Federal Bureau of Biological Survey, begun in 1885.

It is of relevant interest to members of this Society to know that Baron N. De Miklouho-Maclay, in the Proceedings for 1879, warmly advocated the foundation of a Zoological Station at Sydney as "an institution too important for all branches of biology for the idea to be dropped". He also maintained that the combined working of three or four zoological stations, such as in Japan for the northern region, Samoa for the tropical, and in Sydney and New Zealand for the southern zone, should, in a few years, result "in presenting us with a very complete conception of the fauna of the Pacific!" It was not a matter for the Linnean Society alone, he said, but for "every friend of biological science in Australia". In conclusion, Miklouho-Maclay stated that: "The interval between the bringing forward of my proposal (September, 1878) and the actual foundation will afford a good test of the degree and intensity of scientific life in Australia—at least in Sydney."

In 1909, in his Presidential Address to the Zoology Section of the A.N.Z.A.A.S., Charles Hedley, distinguished Conchologist and Past-President of the Linnean Society, stated that "A biological survey should be organized and directed by an institution, such as a museum, a university, or a fisheries bureau". This restricted conception was applied particularly to the marine fauna of Queensland, subsequently investigated by the Great Barrier Reef Committee. However, from subsequent resolutions concerning erosion, afforestation, prickly-pear, the blow-fly, and other faunal problems, it is clear that essential matters of biological survey had been considered by the A.N.Z.A.A.S. many years prior to adoption, by Resolution of the General Council, of the following proposal

by Professor Sir Baldwin Spencer in 1921: "That in order to carry out immediately a co-ordinated Investigation into the Land and Freshwater Fauna and the Flora of Australia and Tasmania, the Societies and Institutions in the various States . . . be requested to co-operate in the work and to take such steps . . . more especially in securing in each State the active assistance of specialists in different branches of Botany and Zoology."

This Resolution, which anticipated the activities of the present war-time Scientific Liaison Bureau, was evidently associated in Baldwin Spencer's view with the foundation in the previous year of the "Commonwealth Institute of Science and Industry", subsequently the C.S.I.R., to which he referred in his Presidential Address to the Association Meeting of 1921, when stressing the fact "that we in Australasia have biological, agricultural, and ethnological problems peculiarly our own, calling aloud for investigation".

In the same year, W. W. Froggatt, when State Government Entomologist, in his Presidential Address to the Royal Zoological Society of New South Wales, reviewed the question of establishing "a Bureau of Biological Survey or a Bureau of Economic Zoology", and traced the history of the United States Bureau, and subsequent Federal legislation regarding the uniformity of State laws. In his Presidential Address to the Linnean Society the following year, Dr. G. A. Waterhouse strongly endorsed the immediate institution of a zoological survey in Australia, pointing out that although the need for such systematic surveys had been recognized in geology and botany, no provision had been made regarding zoology.

At the Wellington Meeting of the Association in 1923 a "Committee for the Investigation into the Land and Fresh-water Fauna and the Flora of Australia and Tasmania" was reappointed. At the Perth Meeting in 1926, the General Council adopted the Zoology Section's recommendation "That it is imperative for the better protection of Australian fauna that there should be greater uniformity in the various Acts of the several States and that *the matter be brought under the notice of the Commonwealth Government which has control of export, with a suggestion that the subject might be made a matter for discussion at the next Premiers' Conference.*"

At the Hobart Meeting in 1928, the General Council of the Association adopted the Zoology Section's recommendation . . . "that the Association draws the attention of the Commonwealth Government and the Government of New Zealand to the wholesale destruction of whales in the adjacent Antarctic seas, and requests that, in conjunction with the Imperial Government, measures be taken to control the whale industry in Southern waters." In spite of the urgency of this submission upon a matter of international policy, and the excessive foreign exploitation of whales in the adjacent Sub-Antarctic and Antarctic waters, concerning which an *Australian Antarctic Dependency* was established in 1933, it appears evident that Commonwealth authority has not been effectively exercised either in the matter of control or exploitation.

The Hobart Meeting also appointed a Committee "to consider the question of a thorough scientific investigation and exploration of the western and south-western coasts and districts of Tasmania". The Committee, with changes of personnel, was reappointed at the Brisbane Meeting of 1930 and, though progress was not reported, the importance of a zoo-geographical survey was reaffirmed. It is notable that the establishment of a very active Committee of Tasmanian Biological Survey in 1937 has not only provided effective collaboration with the State Animals and Birds Protection Board, but the experience gained must prove of great assistance in future deliberations concerning the foundation of an Australian Bureau of Biological Survey.

In 1928, J. R. Kinghorn, C.M.Z.S., Herpetologist and Ornithologist at the Australian Museum, in his Presidential Address to the Royal Zoological Society of New South Wales, reviewed our "Faunal Problems", with especial reference to birds and the study and control methods of the United States Department of Agriculture. Commonwealth control of migratory fauna, and unification of State Protection Acts was advocated, to close the many loop-holes for illegal exploitation. The educative and economic importance of the fauna was stressed, as well as "the great necessity for the establishment of a Government Bureau of Economic Zoology" to keep pace with the Great Powers in the conservation of wild life.

In his Address to the same Society the following year, A. F. Basset Hull, M.B.E., F.R.Z.S., reviewed the subject "Our Native Fauna—A Wasted Asset" from the scientific, aesthetic, and economic viewpoint. He also quoted the majority recommendations of a State Fur-Farming Committee, appointed by the Minister for Agriculture (Mr. H. V. Thorby) in 1929. They are in general accord with the findings of the 1941 Committee appointed by the present Minister, the Hon. W. F. Dunn, upon which I represented the Australian Museum as Mammalogist. Notable additions in the 1929 Report, however, were the following recommendations: "That a royalty be charged in respect of all skins of indigenous animals taken for sale, the money so collected to be used for the approved preservation of the flora and fauna of the State; also *"That the State Government request the Commonwealth Government to make a biological survey regarding seal life in Australia"*.

Dealing with the "Effectual Control" of native fauna "which recognizes no political boundaries", Basset Hull, indicating the wasteful harvesting of our faunal riches, quoted astounding figures for the export value of marsupial skins, and marine products, including pearl and trochus shell, and *bêche-de-mer*, for the period 1921–1928. In stressing the uneconomic slaughter shown by the mainland figures for opossum, wallaby, and kangaroo during 1921–8, it is significantly noted that "exports of the native bear, wombat, and other marsupials were not recorded separately, but appeared to be incorporated under one heading, 'other skins', which may also include domestic animals".

In Tasmania alone, stated Basset Hull, for the five years 1923–7, *the annual total of marsupials' skins taken in open seasons of 2–3 months ranged from 1,040,748 in 1923, to the minimum of 465,240 in the following year.* It is significant, therefore, that the total protection covering the preceding two years 1921–2, merely built up the marsupial population for its decimation in 1923, with a resultant marked decline in the yield of succeeding open seasons. The combined total of kangaroo, wallaby, brush- and ring-tail opossum skins *taken in the five-year period, during open seasons totalling one year, attained the colossal aggregate of 3,980,305.* As a result of this faunal slaughter, *the Tasmanian Government reaped the relatively trifling amount of £68,500 in royalties and licence fees.*

It must be emphasized that the subsequent collaboration of the Tasmanian Fauna and State Protection Boards has evolved the most comprehensive system of State control and conservation of fauna. The above figures, however, were more suggestive of a "five-year plan" for extermination rather than economic exploitation of fauna, which should have been utterly impossible in any State of the Commonwealth which actually controls exportation of fauna. The above brief summary provides unqualified support for Basset Hull's final contention that national neglect of proper provision for the scientifically priceless fauna, irrespective of economic value, calls for the strongest legislative measures, and undivided control.

Ten years later, Basset Hull, in his Address to the 59th Annual General Meeting of the Royal Zoological Society, in 1939, emphasized that our native fauna was still a "wasting asset", no steps having been taken to implement a system of unified control, or even to render the State laws more uniform. Obviously, he stated, "the existence of six separate States, five of which have no natural barriers to their boundaries, and all of which are not in agreement as to species to be protected, and the time of protection, renders the position almost hopeless".

Showing how lack of uniform State laws aids the illicit trapper, it was pointed out that no less than 80 species of the 700 Australian birds are wholly or partly protected in some States, and unprotected in one or more of the other States. A trapper can, therefore, transport protected species across the border and obtain permits for their export as the unprotected species of another State. Similarly, during the Queensland open season for koala in 1927, when approximately 600,000 of the unique marsupial were massacred by about 10,000 licensed trappers, it was an "open secret" of the fur market *"that a large proportion of skins sold during that open season had been illicitly taken during the previous closed season, while many came across the border from New South Wales where the koala was still protected"*.

Stating that fauna protection was not seriously legislated for by any State until 1901, coincidentally the year of Federation, and that illicit trade in skins was rife up to 1939, Basset Hull asserted that owing to the operation of Section 92 of the Commonwealth Constitution Act, nothing could be done to stop the practice—interstate trade being absolutely free. The fact that no Federal action was taken to check the Queensland open season for koala, by limitation of the export of skins, supports his final contention of 1939 that *“If the control of native fauna be placed as one of the subjects for a referendum and adopted, the future of our birds and animals should be provided for”*.

#### BIOLOGICAL SURVEY AND THE CANBERRA MEETING.

Following on my appointment as Hon. Secretary of the Biological Survey of Australia Committee of the A.N.Z.A.A.S., at the Auckland Meeting of 1937, a considerable part of the above summary was prepared for submission to the Committee at the Canberra Meeting in January, 1939. The following Resolutions were framed by the Committee, and adopted by the General Council as a Recommendation to the Commonwealth Government:

1. That since the solution of many economic problems of a biological nature in Australia has been delayed because of the lack of knowledge of the geographical distribution of the different species comprising the fauna, it is desirable that an effort be made to co-ordinate the existing information, and to indicate and initiate lines of inquiry which might be followed by qualified persons carrying out systematic and ecological work in the different States.
2. That the work of a biological survey of Australia should be undertaken by the Commonwealth of Australia, and that the Council for Scientific and Industrial Research should be asked to undertake the task, for the following reasons:
  - (a). The distribution of animal and plant life is not limited by political State boundaries;
  - (b). The work of such a survey, and the cognate duties so important and valuable to Australia, can only be carried out by a permanent scientific department: the C.S.I.R. is the only institution at present in a position to undertake this work;
  - (c). It would be advantageous to the C.S.I.R. itself to have survey work carried out, because its organization includes departments dealing with problems of Entomology, Botany, Agriculture, and Forest Products, which are constantly in need of information, such as a Department of Biological Survey could supply.
  - (d). There would be nothing in such a proposal to prevent the C.S.I.R. Biological Survey Department calling upon specially qualified workers in various States, or enlisting the aid of university departments, museums, State officials, natural history societies or independent amateur workers. The C.S.I.R. already obtains the help of properly qualified persons in this way. The proposal, moreover, has the great advantage that invitations for co-operation would come from a body of experts, who could keep a check on the work. The work deputed to other bodies would thus go to those of recognized qualifications, without unnecessary duplication of effort.
  - (e). The proposal, apart from being the only practical scientific one, would in the end undoubtedly prove financially the most economical.
3. That the proposed Department of Biological Survey should have a small permanent staff to co-ordinate activities in the various States, and if necessary to arrange and even direct such activities.

It is to be understood that, for financial and other reasons, only certain more important aspects of biological survey could be attempted, one of which would be an investigation into the causes of the depletion of certain valuable elements of the Australian fauna.

Reviewing the above detailed summary, and recommendations of the A.N.Z.A.A.S., one might well ask why unified faunal control has not been the subject of Commonwealth action, especially under the Constitutional Amendment proposals for Post-war Reconstruction. Although the desirability of co-ordinated control was apparently unquestioned, there appears to have been a failure to realize that Federal control of fauna and flora, along with conservation of aborigines, is immediately concerned with national and international obligations under the general heading of "Post-war Reconstruction", which is the purpose of the Referendum Bill.

Lack of appropriate Federal action in the past has been due partly to the erroneous supposition that the major problems of wild-life control remain a matter of State administration. There has also doubtless been some unwarranted concern as to whether the States would cease to administer their intrastate faunal Acts. It is significant here to note that the United States Federal control of fauna began with the negotiation of international Migratory Bird Treaty Acts with Canada and Mexico, thus leading to a unified control of interstate fauna. The individual States of the Union retain control of species restricted to them, and may modify schedules within limits of major law, such co-operation being regarded as essential for the preservation of harmony between the Federal and State authorities.

As the co-ordination of Australian faunal management is linked with the establishment of a Commonwealth agency of control, the question also arises as to why the manifold and ever-increasing interstate activities of the Federal C.S.I.R. have not led to the foundation of a co-ordinating bureau of general biological survey. Obviously, it would be impossible to add to the already vast scope of C.S.I.R. operations without adequate governmental provision in the matter of funds and personnel.

Unfortunately, however, in the past the very term "biological survey" seems to have provoked considerable ultra-academic objection, based on entirely obsolete conceptions of the scope and activities of the United States Bureau. The holders of these stultifying views must share the responsibility for the failure to include co-ordinated control of our fast-fading fauna on the Constitution Convention Agenda in 1942. The basic frustration, however, rests with the very fact that there has been no relevant Commonwealth authority, such as a *Federal Ministry of Animal Conservation*, to consider recommendations providing for unified national control, and adequate international representation.

Past criticism of American methods of biological survey was based on some early intensive campaigns against small rodents and large predators, which left an exaggerated impression of vast destruction of fauna. Actually, our own fertile south-eastern region has experienced the tragic trail of the poison-cart, following that of the rabbit, resulting in the wholesale destruction of useful birds and mammals. The decaying rabbit carcasses presumably amplified the blow-fly pest to the wool industry, while the marked increase of grass-hopper plagues evidently reflects the general disturbance of biological balance.

#### FAUNAL RESERVATIONS AND SOIL CONSERVATION.

The rabbit has now extended its activities, so strongly influencing the progress of erosion, to the south-western corner of Western Australia, where the fox was reliably reported in 1937 to be destroying flocks of black swans on the shallow lakes. The spreading of these faunal and economic pests to the fascinating zoo-geographical zone of the south-west, despite fencing barriers often rendered useless against rabbits by erosive drift, and quite ineffective against foxes, underlines the imperative need for adequate national reservations, from which foxes and rabbits are excluded.

Individual States have shown increasing concern for the provision of adequate faunal sanctuaries but, as pointed out in Dr. G. A. Brouwer's book, *The Organisation of Nature Protection in the Various Countries*, sponsored by the Netherlands and American Committees, it is a fact that our larger flora and fauna parks exist mainly for public recreation, rather than for the re-creation of fauna. The control and care of most types of reservations is also utterly deficient in fire, forestry, and faunal supervision.

Regarding the State legislative proposal for the establishment of a "Kosciusko National Park", your Council, as noted in the official section of this Address, considered it necessary to join kindred societies in protesting against the proposal to lease for

grazing purposes the major portion of the Snow Belt area, of some 1,140,000 acres, while reserving a mere 9,000 acres as an experimental sanctuary for three years. Strangely enough, it had been advocated by an expert survey Committee, *evidently exclusive of a biologist*, that the burning-off process conditional with the leases would really favour the fauna by ensuring an abundance of succulent herbage for age-old indigines, many of which are not herbivorous, though actually destroying countless nests and eggs of birds, and small mammals.

It would have been lamentable indeed if a State gesture of such magnificent national import as a floral and faunal reserve should have been too seriously impaired by economic considerations involving grazing of stock and the burning-off of herbage. It is most gratifying therefore to gather that subsequent modifications of the proposal provide for the reservation of approximately one-tenth of the vast Snow Belt as a perpetual primitive area, thus justifying far more significantly the general designation as the Kosciusko National Park.

A recent example of beneficial State action was provided by the New South Wales Government's dedication as a National Fauna Reserve of some 44,000 acres of the Macquarie Marshes, between Warren and Nyngan, as a breeding place for a prolific population of birds and other animals. Such action avoided the American problem of excessive drainage in relation to wild life. Draining of natural swamps increased aridity and erosion, while the reclaimed land was often of a peaty nature down to impervious clay or rock, and generally unsuitable for farming. The public and official reaction to this wasteful despoliation of the breeding places of fishes, birds, and mammals, led to a costly campaign of swamp restoration, which *became* the responsibility of the U.S. Bureau of Biological Survey.

In their report on the "*Vertebrate Animals of Point Lobos Reserve*",\* Professor Joseph Grinnell and J. M. Linsdale, of the University of California, provided the following basic definition: "A State park may be maintained for any one of several justifiable purposes. But the special purpose for which each park is established, and kept, should be clearly understood by all persons directly concerned and responsible for the management of that park. Areas set aside for play, for landscape viewing, or for the broader types of inspiration, may be cared for so as to obtain the greatest utilization possible; but distinction must be made as to the purpose of each particular area and care should be exercised not to confuse, or attempt unwisely to combine, many uses for one small area."

In a comprehensive Intra-Service report of 1938 on "*The Wildlife Conservation Program of the Soil Conservation Service*" of the United States, compiled by the Section Head, Ernest G. Holt, assisted by the "Regional Biologists", occurs this striking introductory statement: "Though inaugurated less than five years ago, and subsequently charged by the 74th Congress with the specific function of controlling erosion, the Soil Conservation Service has now come to be recognized as one of the most potent factors in the United States for wildlife conservation." Defining the term "wildlife" as restricted to denote "undomesticated vertebrate animals", its basic requirements are given in the order of "Cover, Food, and Water".

The Report emphasizes that the union of Soil and Wildlife Conservation Services is based on the fact that both depend fundamentally on the re-establishment and maintenance of vegetation. "Even were there no direct relation between wildlife conservation and operations for the control of erosion", it is stated, "there would still be a strong obligation on the part of the Service to safeguard the wildlife resource in its campaign for the adoption of better land-use practices." This obligation to wild-life conservation, "implied in numerous public utterances of President Roosevelt, Secretary Wallace (Agriculture), and Secretary Ickes (Interior) . . . has been definitely accepted by Federal land-use agencies, such as the Forest Service, the National Park Service, and Farm Security (Resettlement) Administration, whose primary functions are not concerned with wildlife conservation".

The Linnean Society is at present represented at a Conference on the Classification of Parks and Reserves, convened by the National Fitness Council of New South Wales.

\* *Carnegie Institution of Washington*, Publ. No. 481, 1936.

It is hoped to achieve an ordered definition and listing of parks and reserves of the State Crown Lands set aside for "recreation of various kinds and for conservation of natural beauty, flora and fauna, natural or historical monuments, and so forth". The accent here, however, is necessarily on public recreation, but the broader implications of such classification fundamentally involve a national survey of the conservational resources of all States, imperatively linked with the post-war reconstructive activities of closer settlement. The formidable survey, facilitated now by the aerial mapping and road construction of war-time, would be a task for a liaison of scientific and allied services imbued with the high administrative ideals of the United States Services quoted above.

#### FEDERAL AND STATE FAUNAL PROBLEMS.

It is indisputable that Federal unification provides the basic means of adjusting the irregularities of faunal control under diversified State regulations, while providing a national authority in post-war territorial and international deliberations. For example, a Conference of the States on "The Preservation and Protection of Native Fauna" in 1937 proved nationally abortive, because of inadequate State representation, and absence of the Commonwealth as the co-ordinating authority. A letter received after closure of the Conference, expressing the Commonwealth authorities' regret that they had not been represented, stated that "Although the Commonwealth is interested in the subject, *its area of direct administration in regard to these matters is very limited*, and it has been glad to fall into line generally with the policies adopted by State authorities who are more actively concerned . . . with the protection of fauna and flora". Copies of the States' recommendations were requested, however, "*for guidance in connection with the administration of existing laws of the Commonwealth in force in Territories under its control*".

Actually, it was a basic misconception to consider that a Conference dealing with Federal and State faunal responsibilities was entirely concerned with protective legislation. Regarding the limitation of Federal control, it may be pointed out that the Commonwealth controls the export and import of animals, and scientific collections as with geology and anthropology, not only for the States, Papua and the Mandated Territories, but also for the Northern Territory, which lacks any form of faunal administration on State lines.

The duality of State and Commonwealth faunal responsibilities regarding international obligations is illustrated by the excessive foreign exploitation of whales in adjacent waters. It has been pointed out by Sir Douglas Mawson that Australia's share in South Polar exploration culminated in the establishment by British Order-in-Council in 1933 of an *Australian Antarctic Dependency*, covering most of the region between 45 and 160 degrees east longitude. This vast area of about 2,250,000 square miles is, Mawson said, "almost entirely buried under a sheet of ice, and is consequently, at present, but of limited worth. *Very important whale fisheries in the offshore waters are, however, of great immediate value*".

The between-war period of whaling was controlled by a Committee of the League of Nations, and there have been conferences in London, prior to and during the present World War, at which the United States was represented by my friend Dr. Remington Kellogg, Mammalogist at the National Museum at Washington. It appears evident that Commonwealth authority, due possibly to inadequate representation in such matters, has not been effectively exercised in the past either in the control or economics of whaling. Control of post-war whaling within the Antarctic Dependency is a matter for Federal action, while whaling off the Australian coasts must be controlled to prevent destruction of breeding and immature animals.

The past wasteful exploitation of our fur-seal colonies, and present neglect of this economic resource, in favour of exploiting marsupials, provides another field for Federal action. The various seal colonies, extending from southern New South Wales to the south-west of Western Australia, once depleted to the verge of extermination, are now becoming so well stocked about southern Victoria that State investigations have been necessary to contest exaggerated claims of damage to local fisheries. Reckless

exploitation has driven fur-seals from many Sub-Antarctic islands, and the imminence of the extermination of elephant seals and penguins on Macquarie Island, so shocked Sir Douglas Mawson during his observations of 1911-1914 that the island was declared a bird and seal sanctuary in 1916, under annual supervision by the Tasmanian Government. The benefit of such provision, surely a matter for Federal administration in association with whaling, was evident during Mawson's visit to Macquarie Island in 1930 when he was delighted by the restoration of animal life on the isolated sanctuary. It is notable that as far back as 1898 a most comprehensive report by the United States Commission, under Professor David Starr Jordan, which investigated the fur-seal resources of the Pribilof Islands, evolved a system of protective exploitation based on an annual census of populations and the culling of surplus males.

In my Address to the Royal Zoological Society in 1932, and a contribution to the *American Journal of Mammalogy* in 1938, the biological survey problems concerning the Australian mammals were covered in some detail. It should be superfluous here to stress the drastic diminution in both species and populations of the slow-breeding marsupials, such as the smaller members of the kangaroo family (Macropodidae). Several species of rat-kangaroos have become extinct since settlement, while the remaining species, and the quaint hare-wallabies, have vanished from settled regions. The beautiful Toolache Wallaby (*Wallabia greyi*), once plentiful south-east of Adelaide, was coursed for "sport" and marketed so relentlessly that it was reduced to scattered bands by 1910, and finally exterminated. At the present time the same fate threatens the equally beautiful and less shy or speedy Whiptail or Pretty-face Wallaby (*Wallabia elegans*) of coastal New South Wales and Queensland, because of shrinkage of natural habitat due to excessive clearing, and exploitation.

Matters of biological investigation concerning marsupials would include such questions as the actual breeding range of kangaroos, and average grass consumption. These points were involved in recent proposals by some Pastures Protection Boards for the declaration of *an open season of a year's duration for the entire Western Division of the State*. In view of the general inconsistency of the Boards' claims, and the experimental and drastic nature of even a brief Division-wide open season, the Chief Secretary, in consultation with the Australian Museum, has retained the present procedure of declaring limited open seasons for individual districts, with extensions where such are proved necessary.

Any reasonable advocate of nature protection realizes that kangaroos and wallabies cannot be allowed to become a menace to pastoral interests. It is a fact, however, that prejudicial statements of a relatively enormous consumption of grass by kangaroos, in comparison with sheep, are grossly exaggerated. Casual estimates have been published, giving the grass consumption of one kangaroo as actually equalling that of from five to ten sheep. On the contrary, a grazier has reported the running of as many as 24 kangaroos in a three-acre paddock in the Cooma district, without exhausting the food supply, whereas it would require exceptional country to run nine or ten sheep to the same acreage. Such matters should be the subject of factual investigations because, no doubt, the economic damage by kangaroos is over-emphasized as a result of over-stocking of properties, and presence of rabbits, during poor seasons. Continual shrinkage of favourable habitat, in the absence of reservations, tends also to concentrate fauna in the more fertile areas adjacent to settlement, thus creating a false impression of a prolific replacement of marsupial life, and a further invitation to wholesale slaughter.

The arboreal marsupials, however, have never endangered any form of plant life. Some of the larger forms actually assist tree-growth by destroying the parasitic mistletoe, while the small insectivorous and nectar-feeding forms aid the pollination of certain trees, and destroy insect pests. Recently, experiments carried out on behalf of the Queensland Forestry Department indicated that the brush-tail opossum (*Trichosurus*) is probably of economic assistance in controlling the spread of mistletoe as a menace in hardwood forests. It was proved that mistletoe is eaten by opossums in the wild state, while it was actually preferred to a selection of eucalypt leaves and other foods under controlled conditions. Even more important was the observation

that both blossoms and seeds of the parasitic loranth were eaten in all stages, a habit which should be most useful in limiting the spread of mature seeds by birds. A further economic use, as supported by the somewhat restricted experiments, would be the benefit to the honey-producing industry from the opossums' activities reducing the prejudicial effect of mistletoe on the flowering eucalypts, as had been claimed by apiarists.

The members of the "bandicoot" (Peramelidae) family of marsupials are recorded as destroyers of much insect and small rodent life, and it is stated that the early settlers' tolerance of the rabbit-bandicoot or "bilby" (*Macrotis*), once plentiful in western New South Wales, and about Adelaide, was due to recognition of its great vermin-destroying activities. The bilby has since been exterminated near settled areas owing to marketing of the beautiful skins. There are also many references to members of the family Dasyuridae as destroyers of insects, rats, and mice. The value of the fifty odd species of marsupial-mice was stressed by Professor Wood Jones' statement that havoc by insect pests would be greatly reduced if small marsupials were not preyed upon by domestic cats. Captives of the genus *Sminthopsis* have frequently been observed to feed on grass-hoppers which they catch and eat with great relish. The larger members of the family, the brush-tailed phascogales and the "native-" and "tiger-cats" are destroyers of bird-life and poultry, but the depredations are balanced by their destruction of rabbits, rats and mice.

Concerning the economics of the indigenous rat population, it may be stated generally that the fifty odd species are vegetarian and frugivorous bush-haunters which rarely enter habitations. Until recently, excepting in occasional plague occurrences in western Queensland and the Northern Territory, none of them assumed economic importance, and the introduced mouse and rats constituted the problem for control. Lately, however, several indigenous rats have become economically important in the sugar-cane fields of north-eastern New South Wales and Queensland, where they have assumed the rôle of *Rattus norvegicus* as carriers of the leptospirite infection of "Weil's Disease". Outbreaks of the disease have involved the preliminary burning-over of cane crops for the protection of the cutters, and increased harvesting costs. The control problem has demanded much attention from the cane-growers and health authorities, who have submitted more than a thousand specimens, representing at least nine indigenous species, for identification at the Australian Museum.

Considerable series of reptiles, birds, and mammals were also identified at the Museum, to assist the endemic typhus researches of Dr. C. E. M. Gunther, while Medical Officer for Bulolo Gold Dredging Limited. This animal-borne disease of "tick-typhus" or "scrub-itch", involving a high mortality rate, and such afflictions as loss of sight, speech, and hearing, has become a matter of vital concern regarding the health of troops in New Guinea. Collections are being examined at the Museum for Allied and Australian Health Services concerning identification of the animal-reservoirs of endemic typhus, the control of which must become a Commonwealth problem of post-war administration.

Regarding the pre-war trade exploitation of the highly specialized water-rat (*Hydromys*), owing to reduced production of the far more prolific American muskrat, it was significant that statements of economic damage by water-rats coincided with the increased desire for exploitation, just as complaints of opossum damage are made in winter-time when the fur is of the greatest value. Actually, the only economic damage by water-rats is from occasional raids on river-side poultry yards by small colonies which happen to find natural food supplies inadequate. Of far greater importance to pastoralists is the probability that water-rats destroy great numbers of the pond snails which provide the essential intermediate host of the liver-fluke infecting sheep. It has also been stated that the water-rats are of service with certain birds in destroying the freshwater crayfish or "yabbies" which honeycomb the banks of irrigation canals. In view of their dependence upon a restricted aquatic habitat, and slow-breeding habit, these highly specialized rodents could not indefinitely survive intensive exploitation, and protection has been afforded them in Victoria during the summer months, as breeding begins in August and the young are not fully developed until the following April. It is hoped that amendment of the New South Wales Protection Act will remove *Hydromys*

from the unprotected schedule, and that economic control will eventually be established in all States and the Northern Territory.

In the rice-growing irrigation areas of New South Wales, ducks have been the subject of controversy regarding damage to crops, tending to influence claims for prolonged shooting seasons. It has been proved that ducks are not great consumers of rice, and that damage by them in "puddling" amongst the young plants is not as great as that of the Swamp-Hen, and other water-fowl. When the facts were quoted to farmers the general attitude was that ducks must be the culprits as the other birds were not edible! Pastoral interests generally are not aware of the fact that ducks, along with ibis, plovers, and the peewee or magpie-lark, consume great quantities of snail hosts of the liver-fluke. It was noted, however, in the *Proceedings of the Royal Zoological Society* for 1938-9 by Mr. A. W. Bootes, of Sutton, near Cooma, that marked increase in the number of ducks and plovers about his property had "cleaned up all the fluke snails, and I do not drench or inoculate at all" although some neighbours are troubled with both fluke and black disease.

The introduction of foreign fauna presents a most important field for Federal control and investigation, as for example the acclimatization of the American giant toad for control of the sugar-cane beetle in Queensland, where some question has arisen concerning its prejudicial effect on other useful fauna. During preparation of this address, the danger represented by the uncontrolled use of ferrets was stressed by reports that this member of the weasel family was attacking poultry in the Yanco Irrigation Area.

#### BIOLOGICAL SURVEY—AND INTERNATIONAL PROTECTION.

In view of the immediate importance, and difficulties, attaching to national control of fauna and flora, regarding post-war reconstruction, Commonwealth consideration might be given to the convening of a general conference of Federal, State, and C.S.I.R. representatives, in association with the A.N.Z.A.A.S., and other scientific societies, concerning matters of biological control. Is it too much to hope that a division of biological survey may result from such a conference, beginning with a purely advisory "Technical Cabinet" or liaison committee of the C.S.I.R., and other scientific authorities, which could advise upon the obstructive points at issue regarding the scope, personnel, and initial cost of instituting some form of biological survey?

As stressed by the Recommendations of the Canberra Meeting of the A.N.Z.A.A.S. (1939), and my article in the *Australian Journal of Science* (ii(5), 1940), the process of biological survey appears most advantageous to the C.S.I.R., because its activities already embrace departments dealing with the problems of entomology, fisheries, botany and forestry products, agriculture, geology, and soil erosion. A liaison of such services, with the co-operation of a special Information Section, should be readily adaptable for the initiation of a survey programme, and an educational campaign concerning the public attitude towards conservation of biological resources, and the expenditure involved.

The United States Biological Survey was founded in 1885 by the addition of an Economic Ornithology Section to the Division of Economic Entomology, under the Federal Department of Agriculture. The following year, in recognition of their economic importance, a separate Survey Division was formed for the birds and mammals, and it attained the status of a bureau in 1905. There is nothing inconsistent with the history of the American Bureau, and the proposed formation of a Division of Biological Survey within the framework of the C.S.I.R., but rather is there a more imperative need in the absence of a Commonwealth Department of Agriculture. Indeed, the opportunities exceed those of the U.S. Bureau, which is solely concerned with the national resources in vertebrate wild life, excepting fishes and marine mammals which are under the Bureau of Fisheries of the Department of Commerce.

Actually, general enquiries made at Washington indicated that, in the United States, the extremely varied activities of our C.S.I.R. are divided amongst various Divisions and Bureaux of the Departments of Agriculture, Commerce, and the Interior. Thus, the functions of the C.S.I.R., applied even in a purely advisory capacity, should greatly assist in the organization of a biological survey service with a minimum of delay,

dislocation, and expense. It is not possible to list the various U.S. agencies, and acknowledge the helpful reception accorded by their respective Chiefs, and personnel. Consensus of technical opinion was that, following unification of control, biological survey should make a small beginning, with biologists trained in plant and animal ecology and taxonomy.

The desirability of allying the initial work of survey with some serious economic problem, with the promise of impressive results, was emphasized. It is regarded as a basic principle of biological survey, however, that economic considerations shall not alone determine policy, such action having mainly contributed to early criticisms of the U.S. Bureau. A rapid general survey of ecological conditions, and reservation resources, should be the first objective, for which special assignments of the air force—in mapping and photographic reconnaissance—might be engaged with popular appeal.

The basic aims for consideration by a preliminary conference or advisory body concerning biological survey may be briefly summarized as follows:

The proposed Department of Biological Survey should have a permanent staff to arrange, co-ordinate, and direct activities throughout the various States and Territories, including:

1. The conducting of a preliminary general survey of species and approximate populations, and to concentrate on such intensive ecological studies as may become evident.

2. To estimate and advise upon the need for adequate faunal reservations in various regions, capable of sustaining a maximum representation of local flora and fauna.

3. To devise measures for the elimination of prejudicial predators such as the fox, and adequate supervision against destruction by fires, and the public.

4. To advise the respective governments and representatives of industry concerning control of pests, and introduction of exotic fauna, and the control of air-borne and other diseases.

5. To advise upon, and control, the justifiable economic exploitation of fauna, such as excess of male seals, and to apply a percentage of the profits of such exploitation to the cost of faunal control.

6. Education of the public regarding the importance of biological control, and so encourage the checking of erosion, and the proofing of crops against the natural inroads of indigenous fauna, rather than hasten its extermination by demanding general open seasons for uneconomic destruction.

Although these basic aims may appear overwhelming at present, consensus of opinion amongst American authorities is that the mere tabulating of past records and well-established facts is utterly futile. The disharmony of faunal balance in Australia has been tragically increased during the relatively infinitesimal period of settlement, and it has become imperative that representative consultations, actuated by common sense and good will, should co-ordinate measures for protecting our rapidly vanishing fauna.

In view of the successful conclusion of the African Convention, in reconciling the views of some ten participating nations regarding nature protection, a general agreement between the Commonwealth of Australian States surely must be attainable. That major problems of biological control will inevitably arise in the period of international reconstruction is illustrated by the fact that in 1937, the writer, as Australian Museum Mammalogist, at the request of the Commonwealth Government, prepared a list of indigenous mammals, according to the schedules of the African Convention, in anticipation of a proposed international convention for the Protection of the Fauna and Flora of Asia, Australia, New Zealand, and adjacent territories.

It is only during this century that the protection of wild life has received world-wide recognition, as one of the few worth-while human reactions in the midst of international strife and destruction. It is the Commonwealth alone which can represent Australia in the cause of international protection of nature, while fostering national ideals for the conservation of our unique fauna and flora.

The Honorary Treasurer (Dr. A. B. Walkom) presented the Balance Sheets for the year ended 29th February, 1944, duly signed by the Auditor, Mr. S. J. Rayment, A.C.A. (Aust.); and he moved that they be received and adopted, which 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:* W. R. Browne, D.Sc.

*Members of Council:* E. C. Andrews, B.A., W. R. Browne, D.Sc., A. N. Colefax, B.Sc., W. H. Maze, M.Sc., F. H. Taylor, F.R.E.S., F.Z.S., A. B. Walkom, D.Sc.

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

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

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LIABILITIES.		ASSETS.	
£	s. d.	£	s. d.
<b>Capital—</b>		<b>Fixed Assets—</b>	
Amount received from Sir William Macleay during his lifetime	14,000 0 0	Commonwealth Loan, at cost	500 0 0
Further sum bequeathed by his Will	6,000 0 0	Debentures:	
	20,000 0 0	Metropolitan Water, Sewerage and Drainage Board, at cost	494 7 6
	9,423 1 1	Rural Bank of N.S.W., at cost	385 0 0
		Society's Freehold, at cost	11,000 0 0
<b>Contingencies Reserve</b>		Science House (one-third share), at cost	14,756 0 0
	29,423 1 1	Loan on Mortgage	2,500 0 0
			29,636 7 6
<b>Accumulated Funds</b>		<b>Current Assets—</b>	
Commercial Banking Company of Sydney Ltd.	454 19 11	Income Account	255 16 4
Suspense	15 0 0	Cash in hand	10 0 0
Research Donation	9 2 10		
<b>Current Liabilities</b>	479 2 9		
			265 16 4
			£29,902 3 10

INCOME ACCOUNT. Year Ended 29th February, 1944.

	£	s.	d.	£	s.	d.
To Balance from 1942-43	347	5	0	By Subscriptions: 1943-44	140	14 0
" Salaries	389	3	4	Arrears	18	18 0
" Printing Publications	418	18	1	In advance	10	10 0
" Illustrations	51	1	2	Associate	0	10 0
" Rates and Insurance	37	11	0	Entrance Fees	170	12 0
" Postage	19	6	5	Interest	8	8 0
" Petty Cash	56	17	5	Rent	150	0 1
" Audit	10	10	0	Science House	435	4 9
" Printing	22	15	5	Sales (including 60 copies of PROCEEDINGS purchased by Government of N.S.W.)	300	0 0
" Expenses	20	17	3	Fellowships Account (surplus income at 29th February, 1944, transferred)	202	0 8
" Attendance and Cleaning	26	0	0	Balance to 1944-45	610	17 2
" Library	10	0	0		255	16 4
" Pay-roll Tax	2	2	6			
" Bank Expenses	1	0	5			
" Repairs	49	0	0			
	142	5	7			
	£2,132	19	0			

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 29th February, 1944, 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 29th February, 1944, as shown by the books. Certificates of the investments have been inspected.

Sydney, 8th March, 1944.

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

3rd March, 1944.

A. B. WALKOM,  
Hon. Treasurer.

LINNEAN MACLEAY FELLOWSHIPS ACCOUNT.  
BALANCE SHEET at 29th February, 1944.

LIABILITIES.		ASSETS.	
	£ s. d.		£ s. d.
Accumulated Funds—		Fixed Assets—	
Amount bequeathed by Sir William Macleay	35,000 0 0	Commonwealth Loans, at cost	13,000 0 0
Surplus Income Capitalized	14,168 3 3	Metropolitan Water, Sewerage and Drainage Board, at cost	5,425 19 9
		Rural Bank of N.S.W., at cost	1,777 10 0
		Inscribed Stock:	
		Metropolitan Water, Sewerage and Drainage Board, at cost	1,005 0 0
		Loans on Mortgage	27,700 0 0
			<u>48,908 9 9</u>
		Current Assets—	
		Commercial Banking Company of Sydney Ltd.	259 13 6
			<u>£49,168 3 3</u>

INCOME ACCOUNT. Year Ended 29th February, 1944.

	£ s. d.		£ s. d.
To Salaries of Linnean Macleay Fellows	1,600 0 0	By Interest	2,224 0 6
" Pay-roll Tax	13 3 4		
" Balance, being Surplus Income transferred to General Account	610 17 2		
	<u>£2,224 0 6</u>		<u>£2,224 0 6</u>

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 29th February, 1944, 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 29th February, 1944, as shown by the books. Certificates of the investments have been inspected.

Sydney, 8th March, 1944.

3rd March, 1944.

A. B. WALKOM,  
Hon. Treasurer.

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

**BACTERIOLOGY ACCOUNT.**

**BALANCE SHEET at 29th February, 1944.**

LIABILITIES.		ASSETS.	
	£	s.	d.
Accumulated Funds—			
Amount bequeathed by Sir William Macleay ..	12,000	0	0
Accumulated Income Capitalized .. .. .	3,820	0	0
Income Account at 29th February, 1944 .. .. .	15,820	0	0
	989	3	5
	£16,809 3 5		
Fixed Assets—			
Commonwealth Loans, at cost .. .. .			15,820 0 0
Current Assets—			
Commercial Banking Company of Sydney Ltd. ..			388 2 11
Commonwealth Savings Bank .. .. .			595 0 6
Cash in hand .. .. .			6 0 0
	£16,809 3 5		

**INCOME ACCOUNT. Year Ended 29th February, 1944.**

	£	s.	d.
To Salaries .. .. .	831	5	0
" Expenses .. .. .	5	16	11
" Petty Cash .. .. .	1	9	6
" Balance to 1944-45 .. .. .	989	3	5
	£1,827 14 10		
By Balance from 1942-43 .. .. .			800 9 0
" Interest .. .. .			627 5 10
" Donations (Assistant to Bacteriologist) .. .. .			400 0 0
	£1,827 14 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 29th February, 1944, 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 29th February, 1944, as shown by the books. Certificates of the investments have been inspected.

Sydney, 8th March, 1944.

3rd March, 1944.

A. B. WALKOM,  
Hon. Treasurer.

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

## ABSTRACT OF PROCEEDINGS.

### ORDINARY MONTHLY MEETING.

29th MARCH, 1944.

Dr. W. R. Browne, President, in the Chair.

The Donations and Exchanges received since the previous Monthly Meeting (24th November, 1943), amounting to 9 Volumes, 184 Parts or Numbers, 5 Bulletins, 5 Reports and 4 Pamphlets, received from 69 Societies and Institutions and 2 private donors, were laid upon the table.

#### PAPERS READ.

1. Revision of Australian Lepidoptera. Oecophoridae. xi. By A. Jefferis Turner, M.D., F.R.E.S.
2. New or Little-known Species of Australian Tipulidae (Diptera). ii. By Charles P. Alexander, F.R.E.S. (*Communicated by F. H. Taylor, F.R.E.S., F.Z.S.*)
3. Studies in Australian Embioptera. vii. New Embioptera from Tropical Australia. By Consett Davis, D.Sc.

### ORDINARY MONTHLY MEETING.

26th APRIL, 1944.

Dr. W. R. Browne, President, in the Chair.

The President announced that the Council had elected Dr. A. B. Walkom to be Honorary Treasurer for the Session 1944-45.

The President also announced that the Council had elected Professor J. Macdonald Holmes, Mr. R. H. Anderson, Mr. F. H. Taylor and Mr. E. Le G. Troughton to be Vice-Presidents for the Session 1944-45.

Miss June Lascelles and Messrs. F. V. Mercer, B.Sc., D. G. Moye, B.Sc., Dip. Ed., and E. W. R. Thorpe, B.Sc., were elected Ordinary Members of the Society.

The President informed members that the Royal Society of New South Wales will make the sixth award of the Walter Burfitt Prize in November, 1944, to the worker in pure or applied science whose published contributions during the three years ending 31st December, 1943, are considered to be of the highest scientific merit. Nominations and publications should be submitted to the Royal Society not later than 31st August, 1944.

The Donations and Exchanges received since the previous Monthly Meeting (29th March, 1944), amounting to 3 Volumes, 41 Parts or Numbers and 1 Bulletin, received from 22 Societies and Institutions, were laid upon the table.

#### PAPERS READ.

1. Some New Records and New Synonymy of Australian Species of *Anopheles* (Diptera, Culicidae). By A. R. Woodhill (A.A.M.C., Australia) and D. J. Lee.
2. The Subspecies of *Anopheles amictus* Edwards (Diptera, Culicidae). By A. R. Woodhill (A.A.M.C., Australia) and D. J. Lee.
3. A New Species of the Genus *Anopheles* from Northern Australia (Diptera, Culicidae). By D. J. Lee, B.Sc.
4. Origin of the New South Wales Torbanites. By J. A. Dulhunty, B.Sc., Linnean Macleay Fellow of the Society in Geology.

#### NOTES AND EXHIBITS.

Dr. Consett Davis gave a short talk on the Kimberleys.

## ABSTRACT OF PROCEEDINGS.

### ORDINARY MONTHLY MEETING.

31st MAY, 1944.

Mr. E. Le G. Troughton, F.R.Z.S., C.M.Z.S., Vice-President, in the Chair.

The Donations and Exchanges received since the previous Monthly Meeting (26th April, 1944), amounting to 40 Parts or Numbers, 5 Bulletins, 1 Report and 3 Pamphlets, received from 28 Societies and Institutions, were laid upon the table.

#### LECTURES.

##### SOME ASPECTS OF THE NATURAL HISTORY OF NEW GUINEA.

1. *Physiography and Geological History.* By Dr. Ida A. Brown.
2. *The Mammals.* By Mr. Ellis Troughton, F.R.Z.S., C.M.Z.S.
3. *Birds and Shells.* By Mr. Tom Iredale, C.F.A.O.U., F.R.Z.S.

### ORDINARY MONTHLY MEETING.

28th JUNE, 1944.

Dr. W. R. Browne, President, in the Chair.

The President, on behalf of members, offered congratulations to Dr. N. C. W. Beadle, on attaining the degree of Doctor of Science of the University of Sydney.

The Donations and Exchanges received since the previous Monthly Meeting (31st May, 1944), amounting to 1 Volume, 61 Parts or Numbers, 4 Bulletins and 1 Report, received from 24 Societies and Institutions, were laid upon the table.

#### PAPERS READ.

1. Petrology of the Hartley District. v. Evidence of Hybridization in the Moyne Farm Intrusion: A Revision. By Germaine A. Joplin, B.Sc., Ph.D., Linnean Macleay Fellow of the Society in Geology.
2. Notes on Australian Orchids. By Rev. H. M. R. Rupp, B.A.

#### LECTURE.

"New Zealand—Scenic, Geological and Seismological." By Dr. G. D. Osborne.

### ORDINARY MONTHLY MEETING.

26th JULY, 1944.

Dr. W. R. Browne, President, in the Chair.

The President announced that the proclamation protecting certain wild flowers and native plants had been renewed for a further period of three years from 1st July, 1944.

The President also announced that the Oceanography Committee of the Australian National Research Council has arranged a two-day conference at the Council for Scientific and Industrial Research Marine Biological Station, Cronulla, N.S.W., on Friday and Saturday, 18th and 19th August, with the object of bringing into focus the various activities in Australia that contribute to oceanographical knowledge. Details are set out in the *Australian Journal of Science*, vi, No. 6, June, 1944, p. 179.

The Donations and Exchanges received since the previous Monthly Meeting (28th June, 1944), amounting to 1 Volume, 47 Parts or Numbers, 3 Bulletins and 4 Reports, received from 28 Societies and Institutions, were laid upon the table.

#### PAPERS READ.

1. Miscellaneous Notes on Australian Diptera. x. Distribution, Classification and the *Tabanus posticus*-group. By G. H. Hardy.
2. A Modified Respirometer for Studies on the Respiratory Quotient of Apples. By S. M. Sykes, B.Sc.Agr.

3. Studies in the Metabolism of Apples. iv. Further Studies in the Respiratory Metabolism of Granny Smith Apples, with Special Reference to the Importance of Oxygen Supply. By Frances M. V. Hackney, M.Sc., Linnean Macleay Fellow of the Society in Plant Physiology.

4. Studies in the Metabolism of Apples. v. The Respiratory Metabolism of Delicious Apples of Commercial Maturity after Various Periods of Cool Storage. By Frances M. V. Hackney, M.Sc., Linnean Macleay Fellow of the Society in Plant Physiology.

## NOTES AND EXHIBITS.

Miss Valerie May exhibited specimens of *Pterocladia pectinata* (Gepp) Lucas. This species was collected by Mr. A. H. S. Lucas in 1901 and 1910 from New South Wales, and once from New Zealand. Three collections made this year have provided material for study of all the life phases. A related species, *P. lucida* (R. Br.) J. Ag., was also exhibited.

## ORDINARY MONTHLY MEETING.

30th AUGUST, 1944.

Mr. Frank H. Taylor, F.R.E.S., F.Z.S., Vice-President, in the Chair.

The Donations and Exchanges received since the previous Monthly Meeting (26th July, 1944), amounting to 1 Volume, 54 Parts or Numbers, 3 Bulletins and 1 Pamphlet, received from 31 Societies and Institutions, were laid upon the table.

## PAPERS READ.

1. Contributions to a Knowledge of Australian Culicidae. No. vii. By Frank H. Taylor, F.R.E.S., F.Z.S.

2. Arachnid Notes. By Frank H. Taylor, F.R.E.S., F.Z.S.

3. Bryozoa from the Permian of Western Australia. Part i. Cyclostomata and Cryptostomata from the North-West Basin and Kimberley Districts. By Joan Crockford, M.Sc., Linnean Macleay Fellow of the Society in Palaeontology.

## NOTES AND EXHIBITS.

Mrs. A. T. Lee exhibited specimens of a species of *Ophioglossum* collected by Dr. Consett Davis in North Queensland. They are most unusual in that the frond consists of the fertile part or spike only, without any sterile blade, except in one plant where a minute linear structure 1 mm. long occurs in the position of the usual expanded lamina.

Only two such elaminate plants are known to have been collected previously, one in Sumatra (*O. simplex* Ridley apud Bower, *Ann. Bot.*, xviii: 205, 1904), and the other in New Ireland (*O. lineare* Schlechter and Brause, *Bot. Jahrb.*, xlix: 59, 1913), and until the type of *O. lineare* is available for verification, Dr. Davis's interesting discovery has been tentatively identified as that species.

The only differences which it shows from the description and illustration of that species are: (i) its free venation, the veins of *O. lineare* showing occasional anastomoses. A recent monograph on the family indicates that this is not a reliable diagnostic character; (ii) its opaque frond, clearing being necessary before any transparency was achieved; that of *O. lineare* is described as "pellucidus"; (iii) the apiculate apex of the spike, the tip of *O. lineare* being described and illustrated as "rather obtuse"; (iv) the presence of a vertical stock, while *O. lineare* is said to have a "cylindrical rhizome"; this distinction may almost certainly be discounted as the figure of *O. lineare* shows the presence, more concealed than illustrated, of a small stock, while a root is apparently interpreted as the rhizome. The rhizome seen in many Pteridophytes is characteristically replaced by the vertical stock in all known species of *Ophioglossum*.

The collection data for the specimens, which are located at the National Herbarium of New South Wales, Sydney, at the Herbarium of the New England University College, Armidale, and at the Botanic Museum and Herbarium, Brisbane, are as follows: Ravenshoe—Mt. Garnett Road, 6 miles from Ravenshoe, North Queensland, at ca. 3,000 ft., March, 1943, Consett Davis. Growing in open Eucalyptus forest on bare patches of black loam soil between grass tussocks.

## ORDINARY MONTHLY MEETING.

27th SEPTEMBER, 1944.

Dr. W. R. Browne, President, in the Chair.

The President announced that the Council is prepared to receive applications for four Linnean Macleay Fellowships tenable for one year from 1st March, 1945, from qualified candidates. Applications should be lodged with the Secretary, who will afford all necessary information to intending candidates, not later than Wednesday, 1st November, 1944.

The Donations and Exchanges received since the previous Monthly Meeting (30th August, 1944), amounting to 2 Volumes, 38 Parts or Numbers, 2 Bulletins and 1 Pamphlet, received from 32 Societies and Institutions, were laid upon the table.

## PAPERS READ.

1. The Geology of the Albury District. By Germaine A. Joplin, B.Sc., Ph.D., Linnean Macleay Fellow of the Society in Geology.

2. Notes on Australian Boarmiidae and Oenochromidae (Lepidoptera), with Descriptions of New Species. By the late G. M. Goldfinch. (*Communicated by Dr. A. J. Turner.*)

## LECTURE.

A lecture on "Some Aspects of the Kimberley Environment" was delivered by Mr. Maze, M.Sc.

## NOTES AND EXHIBITS.

Mr. E. Cheel exhibited fresh flowering specimens of *Melaleuca* species with purplish coloured flowers, raised from seed collected at Evans Head. Its nearest ally is *M. squarrosa* Sm. The latter is described as having yellowish-white flowers and is illustrated in *Botanical Magazine*, tab. 1935. Specimens of the typical species were gathered at Otford in September, 1902, and at Cataract River in March, 1908. Some specimens apparently with flowers the same colour as those from Evans Head were collected at Burrawang in October, 1888, by the late Mr. J. J. Fletcher.

Mr. Cheel also exhibited specimens of *Melaleuca hypericifolia* Sm., taken from plants cultivated at Ashfield and Concord West. Capsules from flowers in October, 1942, are from 5-7 mm. broad at the base and produce viable seeds; those from 1943 flowers (one year old) are 3 mm. at the base and are immature and do not shed their seeds.

## ORDINARY MONTHLY MEETING

25th OCTOBER, 1944.

Dr. W. R. Browne, President, in the Chair.

The President reminded candidates for Linnean Macleay Fellowships, 1945-46, that Wednesday, 1st November, 1944, is the last day for receiving applications.

The Chairman referred to the death, on 8th September, 1944, of Mr. P. C. W. Shaw, who had been a Member of the Society since 1941.

The Donations and Exchanges received since the previous Monthly Meeting (27th September, 1944), amounting to 4 Volumes, 50 Parts or Numbers, 5 Bulletins and 3 Reports, received from 35 Societies and Institutions, were laid upon the table.

## PAPERS READ.

1. Revision of Australian Lepidoptera. Oecophoridae. xii. By A. Jefferis Turner, M.D., F.R.E.S.

2. Production of Nitrate from Roots and Root Nodules of Lucerne and Subterranean Clover. By H. L. Jensen, Macleay Bacteriologist to the Society, and Dorothy Frith, B.Sc.Agr.

3. Nitrogen Fixation in Leguminous Plants. v. Gains of Nitrogen by *Medicago* and *Trifolium* in Acid and Alkaline Soil. By H. L. Jensen, Macleay Bacteriologist to the Society.

## ORDINARY MONTHLY MEETING.

29th NOVEMBER, 1944.

Dr. W. R. Browne, President, in the Chair.

Miss Mary P. Cash, M.Sc., and Miss Jean J. Liddell were elected Ordinary Members of the Society.

The President referred to the death, on 25th October, 1944, of Dr. C. Anderson, who had been a member of the Society since 1906, a member of Council from June, 1926, to March, 1942, and President, 1932-33.

The President announced that the Council had reappointed Dr. Germaine A. Joplin, B.Sc., Miss Frances M. V. Hackney, M.Sc., and Miss Joan M. Crockford, M.Sc., to Linnean Macleay Fellowships in Geology, Plant Physiology and Palaeontology respectively, for one year from 1st March, 1945.

The Donations and Exchanges received since the previous Monthly Meeting (25th October, 1944), amounting to 3 Volumes, 67 Parts or Numbers, 3 Bulletins, 1 Report and 3 Pamphlets, received from 34 Societies and Institutions and 1 private donor, were laid upon the table.

## PAPERS READ.

1. Studies on Australian Marine Algae. i. By Valerie May, M.Sc.
2. Notes on Australian Mosquitoes (Diptera, Culicidae). Part v. The Genus *Armigeres* and New Species of *Armigeres*, *Theobaldia* and *Culex*. By D. J. Lee, B.Sc.
3. A Critical Revision of R. D. Fitzgerald's "Australian Orchids". By the Rev. H. M. R. Rupp, B.A.
4. Notes on the Geology, Physiography and Glaciology of the Kosciusko Area and the Country north of it. By W. R. Browne, D.Sc., J. A. Dulhunty, B.Sc., and W. H. Maze, M.Sc.

## LIST OF PLATES.

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- ii.—Petrology of the Hartley District.
- iii.—Portrait of Alexander Greenlaw Hamilton.
- iv-v.—Bryozoa from the Permian of Western Australia.
- vi.—Geological Sketch Map of the Albury District.
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## NEW OR LITTLE-KNOWN SPECIES OF AUSTRALIAN TIPULIDAE (DIPTERA). II.

By CHARLES P. ALEXANDER, F.R.E.S., Massachusetts State College, Amherst, Mass., U.S.A.  
(Communicated by Frank H. Taylor, F.R.E.S., F.Z.S.)

(Seven Text-figures.)

[Read 29th March, 1944.]

The preceding part under this general title was published in these PROCEEDINGS in December, 1922 (xlvii (4), 581-590). Since that time a vast amount of work has been accomplished on the crane-flies of Australia and many records of seasonal and geographical distribution have accumulated. It seems advisable that certain of these records be published at this time, together with the descriptions of various undescribed species and subspecies from various States of the Commonwealth.

I am particularly indebted to Mr. Taylor for correcting the date of publication of Skuse's first paper on the Australian Tipulidae. Author's separates of this are labelled as though actually printed on 25th September, 1889. Mr. Taylor spent some time in clearing up this matter, and it is due to his kindness that the following notes may be given. "I have cleared up the mystery re dates mentioned by you and myself. His VII was read on September 25th, 1889 (that is the date of the usual monthly meeting of that year, which I saw by inspecting the notices of the monthly meetings through the kindness of Dr. Walkom) and the part of the journal containing Skuse's paper was published February 3rd, 1890. I am sending you a photograph proving date of publication as on that date. For some curious reason which cannot now be explained, because the original Secretary is now dead, the date of reading and not of publication was printed on the reprints of 1889."—*Frank H. Taylor.*

The specimens upon which the following records are based were taken by various friends and correspondents who are acknowledged in the text and to whom my sincere thanks are extended.

## TIPULINAE.

## CLYTOSMUS HELMSI Skuse.

PROC. LINN. SOC. N.S.W., xv, 1890, 76.

Mount Kosciusko, New South Wales, 2nd February, 1927 (L. Harrison).

## PTILOGYNA RAMICORNIS (Walker).

*Ent. Mag.*, ii, 1835, 469.

Dudley Lagoon, Newcastle, New South Wales; bred from larvae found in lagoon 30th August, 1933; adults emerged 13th and 25th October, 1933 (N. J. B. Plomley); Plomley No. T 1.

## PLATYPHASIA PRINCEPS Skuse.

PROC. LINN. SOC. N.S.W., xv, 1890, 85.

Mount Kosciusko, New South Wales, 2nd February, 1927 (L. Harrison).

## PLATYPHASIA REGINA Alexander.

PROC. LINN. SOC. N.S.W., xlvii, 1922, 586.

Deer Vale, New South Wales, 12th January, 1931 (A. N. Burns); Wilson Collection.

## PLUSIOMYIA NEOGAMA, n. sp.

Allied to *inornata* Skuse; antennae (female) with at least seven bipectinate segments; mesonotal praescutum golden-yellow with three black stripes; femora obscure

yellow, the tips broadly black; wings brown and grey, with a conspicuous creamy-white pattern, including a broad incomplete cross-band beyond the cord, this sending a ray to the wing apex in cell  $R_5$ .

♀. Length about 19 mm.; wing, 15.5 mm.

Frontal prolongation of head elongate, without nasus; brown, darker at base; palpi black. Antennae with basal segment elongate, equal in length to the frontal prolongation, light brown, narrowly blackened at tip; pedicel small, yellow; basal flagellar segments yellow, soon passing into black, with only the apex of segment pale, the branches entirely black; first flagellar segment with a single basal branch that is subequal to the segment; flagellar segments two to eight with a pair of basal branches, the longest nearly twice the segment, in addition to a small subapical median lobule; antenna broken beyond the eighth flagellar segment and possibly with even more branched segments; scape elongate, nearly one-third as long as the entire organ, as in the group. Head grey, with a narrow velvety black median line extending the whole length of vertex.

Mesonotal praescutum golden-yellow with three conspicuous black stripes, the broader median one a little more nitidous; posterior sclerites of mesonotum golden-yellow, the scutal lobes chiefly brownish-black, their lateral portions more greyish; parascutella more pruinose. Pleura brown, heavily grey pruinose; anterior dorsopleural region buffy, the posterior portion more infuscated; dorsal portion of pleurotergite golden-yellow, the lower portion more infuscated. Halteres pale, the knobs dark brown. Legs with the coxae light grey; trochanters brownish-yellow, with a black spot on inner face at apex; femora obscure yellow, the tips broadly black; tibiae obscure yellow, the base narrowly, the tip more broadly brownish-black; tarsi brown, passing into black. Wings with the ground colour brown, the posterior margin broadly grey; an extensive creamy-white pattern, arranged as follows: Bases of anal and cubital cells, in the latter extending to two-thirds the length of cell; outer half of cell M; a broad band beyond cord, extending from costa through cell 1st  $M_2$ , sending a ray to the margin in cell  $R_5$ ; posterior prearcular region, vein  $Cu_1$ , cord, outer end of cell 1st  $M_2$  and outer radial cells beyond the cross-band darker brown; veins brown, luteous in the pale areas. Venation: Cell  $M_1$  broadly sessile, the basal section of  $M_2$  subequal to m.

Abdominal tergites obscure yellow, with three black stripes, the median stripe more widened on the intermediate segments; basal tergite pruinose; segments beyond the second with a yellowish-grey pollen, occupying most of the ground; sternites obscure yellow, the incisures slightly infuscated, the outer segments uniformly pruinose. Ovipositor dark chestnut, the sternal valves more blackened.

*Hab.*—Northern New South Wales.

Holotype, ♀, Brooklana, eastern Dorrigo, altitude about 2,000 feet, October-November, 1929 (W. Heron); Alexander Collection.

*Plusiomyia neogama* is very distinct from the other known species of the genus. From the other members of the *inornata* group in eastern Australia—*inornata* Skuse and *minor* Alexander—the species differs most evidently in the pictured wings and in the increased number of branched antennal segments.

#### PLUSIOMYIA OLLIFFI Skuse.

PROC. LINN. SOC. N.S.W., xv, 1890, 89.

Mount Kosciusko, New South Wales, 2nd February, 1927 (L. Harrison).

#### ISCHNOTOMA EPISEMA Alexander.

*Ann. Mag. nat. Hist.* (9) xiii, 1924, 184.

Yaouk, New South Wales, altitude about 3,500 feet, January, 1931 (Taylor); returned to Taylor.

#### ISCHNOTOMA FASTIDIOSA (Skuse).

PROC. LINN. SOC. N.S.W., xv, 1890, 69.

This was described as a species of *Tanytremna* by Skuse, whose material was from Sydney, Berowra and Lawson, in the Blue Mts., New South Wales. Further material was taken by Tonnoir at Wentworth Falls, Blue Mts., 18th November, 1921. I would regard this as being a species of *Ischnotoma* with unusually long, slender legs. Most

species of the genus have the legs elongate but in this species the tarsi, and especially the basi-tarsi, are very slender. The antennae agree well in structure with one of the groups of the genus except that the ninth to twelfth segments are more elongate to linear, with longer verticils that begin to suggest the very accentuated case found in *Acracantha* Skuse.

Male hypopygium with the ninth tergite narrowed posteriorly, the caudal margin with a deep U-shaped notch, the lateral lobes thus formed having almost the same outline as this notch. Outer dististyle a slender cylindrical rod attached to the base of the large fleshy inner style; this latter enlarged on basal half, before midlength on outer margin with a raised portion that is densely set with blunt blackened nodules; apex of style beyond this point narrowed, the inner or ventral margin lobed.

ISCHNOTOMA FUSCOBASALIS Alexander.

*Ann. Mag. nat. Hist.* (10) xix, 1937, 329.

A female specimen bred from larva taken in mud at margin of permanent stream; mountains above Warburton, Victoria, altitude 3,800 feet, emerged 13th January, 1931 (Wilson); Wilson Collection.

ISCHNOTOMA RUBRIVENTRIS (Macquart).

*Dipt. Exot. Suppl.* i, 1846, 14.

New South Wales: Dorrigo, 2,000 feet, 10th February, 1931; 13th September, 1931 (Heron). A.C.T.: Blundell's, 18th February, 1931 (Tonnoir); Canberra, 1st October, 1930 (Tonnoir).

ISCHNOTOMA SERRICORNIS (Macquart).

*Dipt. Exot. Suppl.* i, 1846, 13.

Sharpening Stone Creek, near Yass, New South Wales; adults, with larval and pupal skins; larvae and pupae taken in thick, wet moss where they were numerous. Larvae eat the green shoots of the moss; very sluggish. Of various specimens, pupal period varied from 9 to 13 days (Miss K. English). Other records.—New South Wales: Dorrigo, 10th February, 1931; 24th September to 30th November, 1931 (Heron). A.C.T.: Blundell's, 18th February, 1931 (Tonnoir).

PHYMATOPSIS NIGRIROSTRIS Skuse.

PROC. LINN. SOC. N.S.W., xv, 1890, 98.

New South Wales: Greenwich, Sydney; male emerged 20th March, 1925; subapterous female emerged 21st March; mated; collector not known, received through Taylor; McMaster's Beach, Kincumber, 22nd April, 1935 (Plomley); School of Public Health and Tropical Medicine, University of Sydney, through Taylor.

HABROMASTIX HILLI Alexander.

PROC. LINN. SOC. N.S.W., xlvii, 1922, 588.

Emerged from lawns, Toorak garden, Melbourne, Victoria, 22nd April, 1929 (V. H. Miller); Wilson Collection.

MACROMASTIX COSTALIS (Swederus).

*K. Vet. Accad. Nya Handl.*, viii, 1787, 286.

New South Wales: Mount Victoria, Blue Mts., 8th December, 1931 (Taylor); Narrabeen, 16th September, 1935 (N. J. B. Plomley); Plomley, No. T 2a; Mount Kosciusko, 2nd February, 1927 (L. Harrison); the male antenna of this specimen measured 48 mm.

NEPHROTOMA AUSTRALASIAE (Skuse).

PROC. LINN. SOC. N.S.W., xv, 1890, 126.

Eungella, via Mackay, Queensland, altitude 2,300 feet, March, 1929 (Taylor).

SEMNOTES IMPERATORIA Westwood.

*Trans. ent. Soc. Lond.*, 1876, 502.

Bendigo, Victoria, December, 1930 (Marc. Cohn); Wilson Collection. "This example is much smaller than one I have from Wentworth Falls, New South Wales. Type of country very different, Bendigo being dry country of very little altitude."—Wilson.

## LEPTOTARSUS CLAVATUS RUFOSTERNATUS, n. subsp.

Close to typical *clavatus* (Macquart), differing in a few minor regards. Thoracic pleura with anepisternum and sternopleurite more or less pruinose, sometimes heavily so. Wings with costal border and arculus dark brown, the stigmal area paler; posterior prearcular region, together with bases of cells R, M, Cu and 1st A, light yellow; a similar yellow area beyond cord in bases of cells R<sub>3</sub> and R<sub>5</sub>. Abdominal sternites reddish-yellow, the second to fourth more or less blackened, especially medially.

*Hab.*—Victoria.

Holotype, ♂, Monbulk, 27th January, 1929 (Wilson); Wilson Collection. Allotype, ♀, Ferntree Gully, 23rd March, 1931 (Wilson); Wilson Collection. Paratype, ♂, Beaconsfield, 30th November, 1930 (Wilson); Alexander Collection.

The holotype has the least amount of pleural pruinosity, this being restricted to the ventral sternopleurite; postnotal mediotergite almost unmarked. The allotype and paratype have the pleura more extensively pruinose and the spots on posterior border of mediotergite are larger and more conspicuous. All specimens have the femoral bases broadly and conspicuously yellow. The allotype shows a curious malformation of both wings, the outer end of cell M having an adventitious cross-vein near its outer end, this cutting off a cell just basad of cell 1st M<sub>2</sub> and approximately one-half as large as this latter.

The exact identity of Macquart's *Tipula clavata* (*Diptères exotiques*, Suppl. 4, 1850: 14-15, pl. 1, fig. 4) remains still in question. His detailed description of the thoracic notum disagrees in many important regards from his figure. The description calls for a species having the basal two abdominal sternites fulvous, the others shiny black. The wings are reddish-brown, the costal margin and stigma darker brown, the wing base yellow. The type-locality is indicated as being "Tasmania", possibly an error.

## LEPTOTARSUS MACQUARTII FLAVOLATERALIS, n. subsp.

Characters generally as in typical *macquartii* (Guérin), differing in the colouration of the thorax.

♀. Length about 20 mm.; wing, 24 mm.

Mesonotal praescutum with the central half chiefly black, the median region again variegated by reddish, brightest on the cephalic portion of the sclerite, more obscure near the suture, these reddish portions evidently representing the usual median stripe, the interspaces black; lateral fourth of praescutum yellow, the usual lateral stripe shiny yellow, the lateral margin of sclerite more golden-yellow pollinose; suture narrowly blackened to wing-base; posterior sclerites of mesonotum clear yellow. Pleura yellow, the anepisternum and sternopleurite dark grey pruinose, a little brightened along caudal margin. Legs beyond the trochanters black, only the extreme base of fore femora on their dorsal surface brightened. Wings chiefly infuscated, the cephalic margin and stigma somewhat darker but not intensely so; wing-base before and beyond arculus vaguely yellowish; bases of cells R<sub>3</sub> and R<sub>4</sub>, similarly slightly yellowish. Abdomen yellow, the caudal margins of tergites one to four, inclusive, black, sending a median spur cephalad; tergites three and four with the bases similarly narrowly blackened; sternites two to four with small median and lateral black spots on caudal margin; outer segments of abdomen with a golden-yellow pollen.

*Hab.*—A.C.T.

Holotype, ♀, Black Mountain, 10th December, 1930 (Tonnoir); returned to Tonnoir.

Despite the partly cinereous thoracic pleura, I am placing the present fly with *macquartii* (Guérin) as a subspecies. Because of insufficient material, the various races or forms of *Leptotarsus* and *Semnotes* seem very puzzling and difficult to define. Whatever their final status, these various forms require some designation by which they may be distinguished.

## DOLICHOPEZA (DOLICHOPEZA) ANNULIPES Skuse.

Proc. Linn. Soc. N.S.W., xv, 1890, 61.

Millgrove, Victoria, 17th January, 1931; "Continually hovering over rock face near Yarra River, altitude 450 feet; very difficult to see when on wing".—Wilson.

## DOLICHOPEZA (DOLICHOPEZA) BREVIFURCA Skuse.

PROC. LINN. SOC. N.S.W., xv, 1890, 66.

Tasmania: Zeehan and Strahan, January-February, 1924 (Hardy).

New South Wales: Brown Mt., 2nd December, 1930 (Tonnoir).

## DOLICHOPEZA (DOLICHOPEZA) DAVIDSONI Alexander.

*Ann. Mag. nat. Hist.*, (10) v, 1930, 137.

Dorrigo, New South Wales, 25th September, 1931 (Heron).

## DOLICHOPEZA (DOLICHOPEZA) PALLIDULA Alexander.

*Ann. Mag. nat. Hist.*, (10) ii, 1928, 338.

Obelisk Bay, Sydney Harbour, 5th January, 1934 (Plomley); Hornsby, New South Wales; larva 17th June, 1934; emerged 17th September, 1934 (Plomley); Plomley, No. T 4.

## DOLICHOPEZA (DOLICHOPEZA) SUBPOSTICATA Alexander.

*Ann. Mag. nat. Hist.*, (10) ii, 1928, 342.

Mountains above Warburton, Victoria, altitude 3,000-4,000 feet, 6th December, 1931 (Wilson).

## DOLICHOPEZA (DOLICHOPEZA) VARIPES Skuse.

PROC. LINN. SOC. N.S.W., xv, 1890, 67.

Mount Victoria, Blue Mts., New South Wales, October, 1930 (Wilson); Wilson Collection.

## CYLINDROTOMINAE.

## STIBADOCERODES TASMANIENSIS Alexander.

*Rec. S. Aust. Mus.*, ii, 1922, 250.

Victoria: Mt. Donna Buang, above Warburton, altitude 3,000-4,000 feet, 6th December, 1931 (Wilson); Ringwood, 25th October, 1931 (Wilson).

## LIMONIINAE.

## LIMONIINI.

## LIMONIA (DICRANOMYIA) KULIN Alexander.

*Ann. Mag. nat. Hist.*, (10) xii, 1933, 336.

New South Wales: near Yass. Larvae taken at Catherine's Creek, in wet moss; from these, three adults emerged. Larvae pupated inside shiny cases and the pupal skins may be inside these cases. I think the larvae live in the cases; they become very active and restless when these latter are broken. Miss K. English.

## LIMONIA (DICRANOMYIA) MARINA (Skuse).

PROC. LINN. SOC. N.S.W., xiv, 1890, 765.

Off South Head, Sydney, New South Wales; 10th November, 1933 (Plomley); off sea-watered wet rock facing the sea.

## LIMONIA (GERANOMYIA) GRUS Alexander.

*Ann. Mag. nat. Hist.*, (10) xii, 1933, 346.

Male bred from a pupa in a gelatinous cocoon in running water; 18th February, 1931, Blundell's, A.C.T. (Tonnoir).

## HELIUS (HELIUS) MESORHYNCHUS Alexander.

*Ann. Mag. nat. Hist.*, (10) xii, 1933, 350.

Blundell's, A.C.T., 30th January, 1930 (L. F. Graham).

## HELIUS (HELIUS) VENUSTUS (Skuse).

PROC. LINN. SOC. N.S.W., xiv, 1890, 790.

Brooklana, Dorrigo, New South Wales, 20th September, 1931; 29th October, 1932 (Heron).

*HELIUS (EURHAMPHIDIA) NIVETAEISIS* (Skuse).

PROC. LINN. SOC. N.S.W., xiv, 1890, 791.

Brooklana, Dorrigo, New South Wales, 20th September, 1931; 23rd February, 1932 (Heron).

*TONNOIROMYIA TASMANIENSIS* Alexander.

*Ann. Mag. nat. Hist.*, (9) xvii, 1926, 192.

Victoria: Mountains above Warburton, 22nd December, 1929; altitude 3,000–3,800 feet, 2nd March, 1930; April, 1931 (Wilson).

## PEDICIINI.

*PEDICIA (TRICYPHONA) NIGRITARSIS* (Skuse).

PROC. LINN. SOC. N.S.W., xiv, 1890, 888.

Victoria: Donna Buang, above Warburton, altitude 3,000–4,000 feet, 6th December, 1931; 1 ♀ with heavily patterned wings and with cell  $M_2$  open by the atrophy of  $m$ ; Wilson Collection.

New South Wales: Larvae taken in wet moss in a stream near the top of Waroo Hill, near Yass, altitude 2,100 feet. Larvae very active, pupating within a tube composed of moss scraps; larva 25th September, 1933; pupated 3rd October, emerged 14th October; pupal duration 11 days.—Miss K. English.

## HEXATOMINI.

*AUSTROLIMNOPHILA ANTIQUA* (Skuse).

PROC. LINN. SOC. N.S.W., xiv, 1890, 849.

Brooklana, Dorrigo, New South Wales, altitude 2,000 feet, October–November, 1929; Dorrigo, 9th January, 1931; 16th August, 1931; 20th September, 1931 (Heron).

*AUSTROLIMNOPHILA INTERVENTA* (Skuse).

PROC. LINN. SOC. N.S.W., xiv, 1890, 850.

Brooklana, Dorrigo, New South Wales, altitude 2,000 feet, October–November, 1929; Dorrigo, 16th August, 1931; 20th September, 1931 (Heron).

*LIMNOPHILA ANTENNELLA* Alexander.

*Ann. Mag. nat. Hist.*, (10) iii, 1929, 482.

Mt. Donna Buang, above Warburton, Victoria, altitude 3,000–4,000 feet, April, 1931 (Wilson).

*LIMNOPHILA AUREOLA* Skuse.

PROC. LINN. SOC. N.S.W., xiv, 1890, 843.

Victoria: Beenak, 9th March, 1930 (Wilson); mountains above Warburton, altitude 3,000–3,800 feet, 2nd March, 1930; April, 1931 (Wilson).

*LIMNOPHILA AUSTRALPINA* Alexander.

*Ann. Mag. nat. Hist.*, (10) iii, 1929, 474.

Blundell's, A.C.T., 21st December, 1930 (Tonnoir).

*LIMNOPHILA BORCHI* Alexander.

*Ann. Mag. nat. Hist.*, (10) iii, 1929, 486.

Mountains above Warburton, Victoria, April, 1931 (Wilson).

*LIMNOPHILA BRUNNEISTIGMA* Alexander.

*Ann. Mag. nat. Hist.*, (10) viii, 1931, 151.

Mt. Donna Buang, above Warburton, Victoria, altitude 3,000–4,000 feet, April, 1931 (Wilson).

*LIMNOPHILA EFFETA* Alexander.

*Rec. S. Aust. Mus.*, ii, 1922, 244.

Dorrigo, New South Wales, altitude 2,000 feet, 20th June, 1931 (Heron).

## LIMNOPHILA HILLI Alexander.

*Ann. Mag. nat. Hist.*, (10) iii, 1929, 485.

Mountains above Warburton, Victoria, April, 1931 (Wilson).

## LIMNOPHILA INTONSA Alexander.

*Ann. Mag. nat. Hist.*, (10) i, 1928, 228.

Ringwood, Victoria, 15th November, 1931 (Wilson).

## LIMNOPHILA KERSHAWI KERSHAWI Alexander.

*Ann. Mag. nat. Hist.* (10) i, 1928, 219.

Warburton, Victoria, 6th December, 1931 (Wilson).

## LIMNOPHILA KERSHAWI CUMBERLANDENSIS Alexander.

*Ann. Mag. nat. Hist.*, (10) viii, 1931, 152.

Mt. Donna Buang, altitude 3,000–4,000 feet, 6th December, 1931; 2nd March, 1930 (Wilson).

## LIMNOPHILA KERSHAWI DANDENONGENSIS Alexander.

*Ann. Mag. nat. Hist.* (10) viii, 1931, 152.

Bred from a pupa taken in mud at stream margin; mountains above Warburton, Victoria, altitude 3,500 feet, emerged 14th March, 1931 (Wilson). Also taken at Belgrave, Victoria, 26th April, 1931 (T. Tregellas).

## LIMNOPHILA LEPIDA SUBTILIS, n. subsp.

♀. Length about 3.8 mm.; wing, 4.3 mm.

Rostrum and palpi dark brown. Antennae brownish-black throughout; flagellar segments elongate, with long delicate verticils. Head brown, the anterior vertex and posterior orbits more greyish.

Mesonotum brown, with a very sparse yellowish pollen laterally, the median region clearer brown; pseudosutural foveae and tuberculate pits dark brown, about on a common transverse level; scutum dark brown; scutellum brown, paler caudally; postnotum dark, pruinose. Pleura pale brown, with two dark brown longitudinal lines, the more ventral one occupying the sternopleurite; dorsal stripe passing from above the fore coxae to beneath the wing-root, becoming obsolete on the pleurotergite. Halteres pale yellow throughout. Legs with the coxae yellow; trochanters testaceous-yellow; femora brownish-yellow; tibiae and tarsi a little darker; terminal tarsal segments dark brown; segments of legs with conspicuous sub-erect setae. Wings obscure cream colour, with a darker pale brown pattern that appears as transverse bands and as broad seams and spots, the pattern arranged as follows: Bases of cells R and M, in alignment with a conspicuous axillary cloud; a broad transverse band at level of origin of Rs, broken in cell M, including a conspicuous quadrate area at Rs and a larger one at the end of vein 2nd A, the latter crossing cells Cu and 1st A; stigma slightly darker brown; a broad complete seam at cord and another at end of cell 1st M<sub>2</sub>; large paler clouds at ends of veins R<sub>3</sub>, R<sub>4</sub>, M<sub>3</sub>, M<sub>4</sub> and Cu<sub>1</sub>; additional clouds at forks of R<sub>2-3+4</sub> and M<sub>1+2</sub>; veins pale, darker in the patterned areas. Venation: Sc relatively long for a member of the *ocellata* group, ending about opposite three-fourths the length of the long arcuated Rs, Sc<sub>2</sub> some distance from tip of Sc<sub>1</sub>, the latter alone considerably longer than m-cu; R<sub>2-3+4</sub> fully one-half longer than m-cu; R<sub>2</sub> subequal to R<sub>1+2</sub>, placed just beyond fork of R<sub>2+3+4</sub>; R<sub>2+3</sub> being punctiform to obliterated; cell R<sub>3</sub> gently widened at distal end; inner ends of cells R<sub>4</sub>, R<sub>5</sub> and 1st M<sub>2</sub> in transverse alignment; cell M<sub>1</sub> shorter than its petiole; m-cu about its own length beyond the fork of M.

Abdominal tergites dark brown, the sternites somewhat paler. Ovipositor with cerci very long and slender, pale horn colour.

*Hab.*—Northern New South Wales.

Holotype, ♀, Eastern Dorrigo, 8th January, 1927 (W. Heron); Alexander Collection.

Of typical *lepida* Alexander I have seen only males. The possibility is not excluded that the present fly may be the female of this species.

## LIMNOPHILA PANTHERINA Alexander.

*Rec. S. Aust. Mus.*, ii, 1922, 245.

New South Wales: Wentworth Falls, Blue Mts., January, 1932 (Taylor); Dorrigo, altitude 2,600 feet, 16th August, 1931 (Heron). A.C.T.: Blundell's, 18th February, 1931 (Tillyard).

## LIMNOPHILA POLYMEROIDES Alexander.

*Ann. Mag. nat. Hist.*, (10) iii, 1929, 473.

Mountains above Millgrove, Victoria, 19th January, 1931; Mt. Donna Buang, altitude 3,000-4,000 feet, April, 1931 (Wilson).

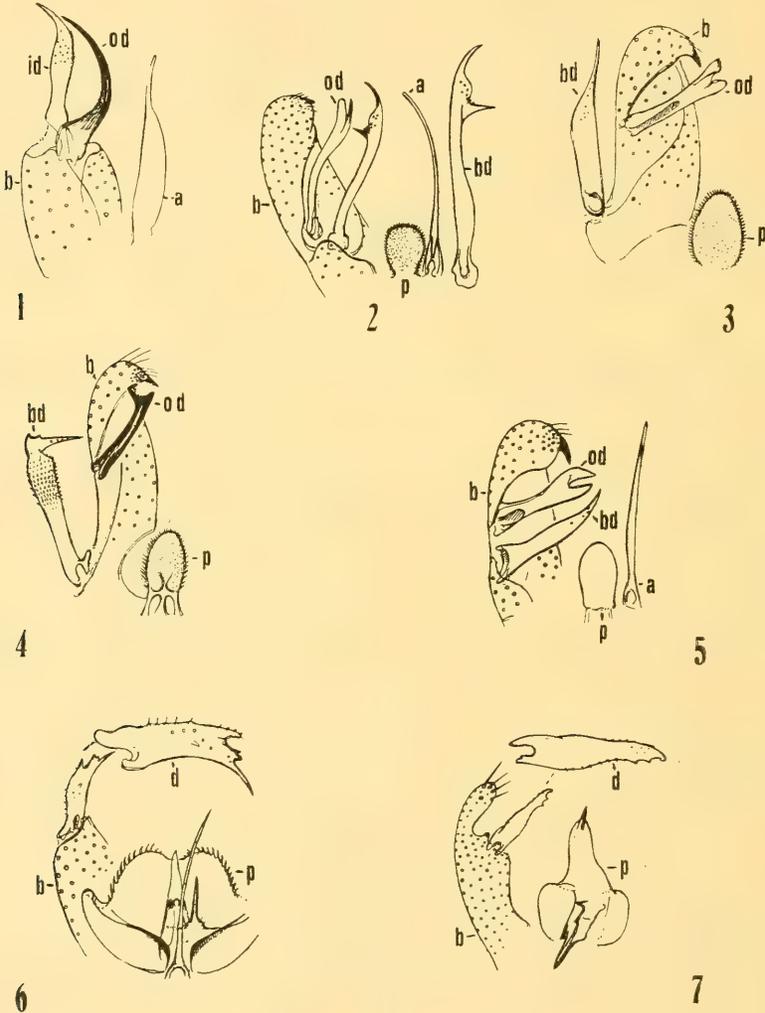


Fig. 1.—*Molophilus (Molophilus) mancus*, n. sp.; male hypopygium. Fig. 2.—*Molophilus (Molophilus) perpendicularis*, n. sp.; male hypopygium. Fig. 3.—*Molophilus (Molophilus) abitus*, n. sp.; male hypopygium. Fig. 4.—*Molophilus (Molophilus) eboracensis*, n. sp.; male hypopygium. Fig. 5.—*Molophilus (Molophilus) laevistylus*, n. sp.; male hypopygium. Fig. 6.—*Tasiocera (Tasiocera) proluxa*, n. sp.; male hypopygium. Fig. 7.—*Tasiocera (Tasiocera) cascadenis*, n. sp.; male hypopygium.  
*a*, aedeagus; *b*, basistyle; *bd*, basal dististyle; *d*, dististyle; *id*, inner dististyle; *od*, outer dististyle; *p*, phallosome.

## LIMNOPHILA RECEDENS Alexander.

*Ann. Mag. nat. Hist.*, (10) viii, 1931, 147.

Mountains above Warburton, Mt. Donna Buang, altitude 3,000–4,000 feet, 6th December, 1931 (Wilson).

## LIMNOPHILA SUBTRISTIS Alexander.

*Ann. Mag. nat. Hist.*, (10) i, 1928, 227.

Narooma, New South Wales, 25th November, 1930 (Tonnoir). Costal fringe of male shorter than in type but male hypopygium identical.

## DIEMENOMYIA PRAETENUIS INTERMEDIALIS, n. subsp.

♂. Length 5–5.5 mm.; wing, 6–6.3 mm.; antenna, 3.8–4 mm.

Antennae (male) 19- to 21-segmented, the flagellar segments moderately incised, about midway in degree between the strongly protuberant segments of *bubosa* and the slightly enlarged ones of *praetenuis*. I am referring the present fly to the vicinity of *praetenuis* rather than to *bubosa* because of the length and coarseness of the setae covering the flagellum, these being almost as long and stout as are the normal verticils. Legs black, only the femoral bases yellow. Wings with abundant macrotrichia in outer cells.

*Hab.*—Tasmania.

Holotype, ♂, Wombat Moor, National Park, altitude 3,500 feet, 15th January, 1933 (F. E. Wilson); Wilson Collection. Paratopotypes, 4 ♂♂.

## ATARBA (ISCHNOTHRIX) GENEROSA (Alexander).

*Rec. S. Aust. Mus.*, ii, 1922, 238.

Brooklana, eastern Dorrigo, New South Wales, 7th to 20th May, 1928; 1st to 6th June, 1931 (Heron).

## ATARBA (ISCHNOTHRIX) VERTICALIS FUSCOMACULA, n. subsp.

♂. Length about 6.5 mm.; wing, 7.5 mm.; antenna about 8.5 mm.

♀. Length about 6 mm.; wing, 5.7 mm.

Almost as in typical *verticalis* Alexander; antennae (male) a little shorter; wings heavily patterned.

Antennae of male about one-third longer than the body. Mesonotal praescutum with the stripes grey, the interspaces dark brown; median stripe very broad, the lateral stripes correspondingly reduced. Halteres chiefly pale yellow. Legs with the coxae dark; trochanters yellow, suffused with dark brown at apex of lower face; femora with subterminal black ring slightly wider than in the typical form. Wings with the dark pattern much more extensive than in typical *verticalis*, including the following areas that are lacking or greatly reduced in this form: Bases of cells R and M; origin of Rs and central area in cell M; Sc<sub>2</sub>; R<sub>3</sub> and R<sub>4</sub>; major areas occur in cells Cu, 1st A and 2nd A. Venation: Sc<sub>1</sub> ending about opposite three-fifths (female) to four-fifths (male) the length of Rs; R<sub>2</sub> nearly vertical in position; m-cu at or shortly beyond the fork of M; cell 2nd A narrow. Abdomen dark brown, the caudal margins of the sternites narrowly silvery. Male hypopygium almost as in typical *verticalis*, especially in the bispinous gonapophyses.

*Hab.*—A.C.T.

Holotype, ♂, Blundell's, 18th February, 1931 (Tonnoir); returned to Tonnoir. Allotopotype, ♀; author's collection.

## ERIOPTERINI.

*Conosia irrorata* (Wiedemann).

*Ausseeur. zweifl. Insekt.*, i, 1828, 574.

Eastern Dorrigo, New South Wales, 1st to 6th June, 1931 (Heron).

## GYMNASTES (PARAGYMNASTES) FASCIPENNIS (Thomson).

*K. svenska Frigatten Eugenes. Zool.*, i, Insecta., 1869, 443.

Katoomba, New South Wales, 20th January, 1921 (in American Museum of Natural History, New York).

## ERIOPTERA (ERIOPTERA) DIPLACANTHA Alexander.

*Ann. Mag. nat. Hist.*, (10) vii, 1931, 33.

Eastern Dorrigo, New South Wales, 20th September, 1931 (Heron).

## ERIOPTERA (ERIOPTERA) LUCERNA Alexander.

*Ann. Mag. nat. Hist.*, (9) xvii, 1926, 184.

Homebush, New South Wales, 9th June, 1931 (C. Borch); Wilson Collection.

## MOLOPHILUS (MOLOPHILUS) ABITUS, n. sp.

Belongs to the *plagiatus* group; the general colouration reddish-brown; antennae (male) elongate; flagellar segments fusiform, with long outspreading verticils; male hypopygium with the basal dististyle a flattened blade, at beyond two-thirds the length narrowed into a long straight spine; phallosomic plate oval, the surface with abundant erect setulae.

♂. Length about 3.5 mm.; wing, 4 mm.; antenna about 3.5 mm.

Rostrum light brown; palpi darker brown. Antennae (male) elongate, dark brown; flagellar segments beyond the second elongate-fusiform, with unusually long, outspreading verticils. Head dark grey.

Thoracic dorsum reddish-brown, the posterior sclerites darker. Pleura light brown, the ventral sclerites paler. Halteres dusky. Legs with the coxae and trochanters yellow; remainder of legs brown, the femoral bases paler, the outer tarsal segments brownish-black. Wings greyish, the base slightly more yellow; veins and macrotrichia brown. Venation:  $R_{2+3}$  unusually short,  $R_2$  lying just beyond the level of r-m; petiole of cell  $M_3$  long, approximately three times m-cu; vein 2nd A relatively short, ending some distance before the level of m-cu.

Abdomen, including hypopygium, dark brown. Male hypopygium (Fig. 3) with the beak of basistyle, *b*, moderately stout, straight, blackened, the margin just beyond the origin with small roughenings. Outer dististyle, *od*, with the fork shallow, the outer or lateral blade irregularly roughened at apex. Basal dististyle, *bd*, of distinctive shape, black throughout, appearing as a flattened straight blade, at beyond two-thirds the length narrowed into a long straight spine, its tip acute; distal half of style, including the base of the spinous portion, with scattered setigerous punctures. Phallosomic plate, *p*, oval, the outer end obtuse, the surface with abundant erect setulae.

*Hab.*—Northern New South Wales.

Holotype, ♂, Cascade, January, 1934 (F. E. Wilson); Wilson Collection. Paratopotypes, 2 ♂♂.

The present fly is related to various species that centre about *longicornis* Skuse, all more or less similar in general appearance but differing greatly in the structure of the male terminalia. In the present fly this structure, and especially the basal dististyle, is distinctive.

## MOLOPHILUS (MOLOPHILUS) EBORACENSIS, n. sp.

Belongs to the *plagiatus* group; general colouration dark brown; antennae (male) long, the segments elongate-fusiform, dark brown; male hypopygium with beak of basistyle unusually slender; basal dististyle a powerful straight rod, at apex bent at more than a right angle into a long straight spine, the style before this point with abundant spinulae; phallosomic plate oval, densely setiferous.

♂. Length about 4.2 mm.; wing, 4.7 mm.

Rostrum brownish-black; palpi black. Antennae (male) elongate, broken beyond the base in the unique type but evidently about as long as the wing when entire, brownish-black throughout; flagellar segments elongate-fusiform, narrowed at distal ends into slender necks, their bases with whorls of verticils that are shorter than the segments. Head dark, discoloured in type.

Thorax almost uniform dark brown, including the pleura, the surface sparsely pruinose; pretergites and the humeral region of praescutum restrictedly yellow; no evident praescutal stripes; scutellum unbrightened. Halteres dusky yellow, the bases a little clearer. Legs with the coxae and trochanters yellow; remainder of legs somewhat

darker yellowish-brown, the outer tarsal segments blackened; fore tibia with the sub-basal enlargement broad and ill-delimited. Wings brownish-grey, the base a little brightened; veins and macrotrichia pale brown. Venation: Vein 2nd A short, ending some distance before the level of m-cu.

Abdomen, including hypopygium, brownish-black. Male hypopygium (Fig. 4) with the beak of basistyle, *b*, unusually slender. Outer dististyle, *od*, with the apical fork relatively shallow, the inner blade short. Basal dististyle, *bd*, a powerful straight rod, near apex bent at more than a right angle and thence produced into a long, straight, slender spine, the surface of which has a few setigerous punctures; distal half of style, before the bend, with conspicuous blackened spinous points, those of the inner margin larger and erect, on the outer edge even more conspicuous but few in number. Phallosomic plate, *p*, oval, densely long-hairy. Aedeagus relatively slender.

*Hab.*—Northern New South Wales.

Holotype, ♂, Ebor, January, 1934 (F. E. Wilson); Wilson Collection.

This species is allied to *Molophilus (Molophilus) abitus*, n. sp., *M. (M.) fusiformis* Alexander, and *M. (M.) longicornis* Skuse, differing from all in the structure of the male hypopygium, especially the basal dististyle.

#### MOLOPHILUS (MOLOPHILUS) EXPANSISTYLUS Alexander.

*Ann. Mag. nat. Hist.*, (10) iii, 1929, 344.

South Queensland: Eukey, January, 1934 (Wilson). Hitherto known only from Victoria.

#### MOLOPHILUS (MOLOPHILUS) FROGGATTI Skuse.

*Proc. Linn. Soc. N.S.W.*, xiv, 1890, 807.

Wentworth Falls, Blue Mts., New South Wales, December, 1931, to January, 1932 (Taylor).

#### MOLOPHILUS (MOLOPHILUS) LAEVISTYLUS, n. sp.

Belongs to the *plagiatus* group; size small (wing, male, under 3 mm.); general colouration of mesonotum pale fulvous, the posterior sclerites and the pleura darker; antennae relatively short, the basal flagellar segments with unusually long verticils; halteres dark brown; wings brownish-yellow, the veins very slightly darker; male hypopygium with the basal dististyle a simple, very gently curved horn that narrows to the acute tip, on apical third with a few small scattered punctures; phallosomic plate glabrous.

♂. Length about 2.2 mm.; wing, 2.7 mm.; antenna about 0.6 mm.

Rostrum and palpi brown. Antennae brown, relatively short, as shown by the measurements; basal flagellar segments short-oval, the outer ones more elongate; the more basal segments with unusually long verticils on both faces, the outer segments with the longest series on the outer face only to produce a unilateral distribution; on outer segments, all verticils relatively short and inconspicuous; longest verticils (about flagellar segment two) about four times the segment. Head grey.

Pronotum pale fulvous; pretergites and lateral praescutal borders pale yellow; remainder of mesonotum almost uniform fulvous, the postnotum darker. Pleura chiefly infuscated. Halteres relatively short, dark brown, the base of stem restrictedly pale. Legs with the fore coxae weakly darkened, the middle and hind pairs more yellowish; trochanters yellow; remainder of legs broken. Wings with a brownish-yellow tinge, the veins very slightly darker; macrotrichia brown. Venation:  $R_2$  lying a short distance proximad of r-m; petiole of cell  $M_2$  about twice m-cu; vein 2nd A relatively long but nearly straight, ending about opposite the level of m-cu.

Abdomen light brown, the pleural region narrowly darker brown; hypopygium more brownish-yellow. Male hypopygium (Fig. 5) with the beak of basistyle, *b*, relatively stout and blackened, the tip subacute. Outer dististyle, *od*, relatively short and stout-stemmed, the apical fork relatively shallow. Basal dististyle, *bd*, a little shorter than the outer style, appearing as a simple, very gently curved horn that narrows to the acute tip, on apical third with a few small scattered punctures but with no further armature. Phallosomic plate, *p*, oval, the apex obtuse, the surface glabrous.

*Hab.*—Northern New South Wales.

Holotype, ♂, Cascade, January, 1934 (F. E. Wilson); Wilson Collection.

The present fly is amply distinct from all generally similar allies in the structure of the male hypopygium. Among the described species, it is closest to *Molophilus (Molophilus) gilvus* Alexander, of Tasmania, differing in the hypopygial details, especially the nearly smooth basal dististyle of distinctive conformation. Certain other species that have a basal dististyle of approximately similar shape, such as *M. (M.) abitus*, n. sp., and *M. (M.) fusiformis* Alexander, both of northern New South Wales, actually belong to a distinct sub-group of the genus, having elongate antennae in the male sex and with the phallosomic plate densely setiferous.

*MOLOPHILUS (MOLOPHILUS) MANCUS*, n. sp.

Belongs to the *gracilis* group and subgroup; allied to *truncatus*; general colouration dark grey, the praescutum with four darker brown stripes; wings subhyaline, with a brown seam along cord and the distal section of vein Cu; male hypopygium without distinct lobes on basistyle; two dististyles, both acutely pointed at their tips; aedeagus conspicuously widened on basal two-thirds.

♂. Length about 3.5 mm.; wing about 4.3 mm.

Rostrum grey; palpi black. Antennae broken. Head grey.

Mesonotal praescutum brownish-grey, clearer grey laterally, with four relatively distinct, darker brown stripes; pseudosutural foveae dark; posterior sclerites of notum dark grey, the posterior border of scutellum a little more reddish-brown. Pleura brownish-grey. Halteres broken. Legs with the coxae brownish-grey; trochanters yellow; remainder of legs dark brown to brownish-black, the femoral bases brighter. Wings subhyaline; a broken brown seam along cord, including distal section of Cu<sub>1</sub>; veins pale brown, darker in the clouded areas; macrotrichia brown. Venation: R<sub>2</sub> about in transverse alignment with r-m; petiole of cell M<sub>3</sub> a little more than twice m-cu; vein 2nd A relatively long, ending about opposite the caudal end of m-cu.

Abdomen broken, excepting the hypopygium, which is black. Male hypopygium (Fig. 1) with the two dististyles terminal; basistyle, *b*, without evident lobes. Outer dististyle, *od*, a slender curved blackened rod from an enlarged base. Inner dististyle, *id*, a little shorter, expanded at near midlength, the tip acute; surface at near midlength and beyond with several setigerous punctures. Aedeagus, *a*, unusually wide on basal two-thirds, the distal portion narrowed.

*Hab.*—Victoria.

Holotype, ♂, Swift's Creek, January, 1935 (F. E. Wilson); Wilson Collection.

This is a puzzling fly that shows several points of resemblance to *Molophilus (Molophilus) truncatus* Alexander and allies, yet seems to lack certain of the genitalic structures possessed by these latter species, including the modified ventral lobe of the basistyle. I can see no sign of injury to this part of the fly and believe the genitalia as described and figured to be normal. The unusually broad aedeagus furnishes a character possessed by relatively few local species of the genus but is found in *truncatus* and allies.

*MOLOPHILUS (MOLOPHILUS) PERPENDICULARIS*, n. sp.

Belongs to the *plagiatus* group; *annulipes* subgroup; general colouration pale yellow; legs yellow, unpatterned except for the darkened distal tarsal segments; wings deep yellow, the supra-arcular darkened spot small; male hypopygium with the dorsal lobe of basistyle unarmed; basal dististyle a straight rod, at apex narrowed into a slightly curved spine; before apex at near three-fourths the length with a similar erect black spine; phallosomic plate setuliferous.

♂. Length about 3.5 mm.; wing, 4 mm.; antenna about 1.3 mm.

Rostrum yellow; palpi dark brown. Antennae with scape light yellow, pedicel a trifle darker; flagellum brown; flagellar segments relatively elongate, subcylindrical to slightly widened before midlength, with long conspicuous verticils, the longest unilaterally distributed and exceeding twice the length of the segments. Head light yellow, darker beneath.

Pronotum reddish-yellow, darkened laterally. Mesonotum reddish-yellow to yellow, without distinct markings; lateral praescutal border clear yellow. Pleura uniformly pale yellow. Halteres yellow throughout. Legs with all coxae and trochanters pale yellow; a single leg (hind) remains; uniform yellow with the two outer tarsal segments uniformly darkened. Wings a deep yellow, even more saturated in the prearcular and costal fields and along vein Cu; a small but very conspicuous oval brown spot in cell Sc above arculus; veins deep yellow; trichia pale brownish-yellow. Venation:  $R_2$  lying immediately basad of the transverse level of r-m; petiole of cell  $M_2$  about one-third longer than m-cu; vein 2nd A relatively long, ending immediately before the caudal end of m-cu.

Abdomen, including hypopygium with the exception of the blackened tips of the dististyles, uniformly yellow. Male hypopygium (Fig. 2) with the beak of basistyle, *b*, unusually small and insignificant, blackened; dorsal lobe of basistyle unarmed. Outer dististyle, *od*, long and sinuous, the bifid head black, the inner blade narrowed into an acutely pointed spine. Basal dististyle, *bd*, about equal in length, blackened on less than distal half, narrowed into a curved blackened apical spine; at about three-fourths the length bearing a perpendicular black spine, with two or three small denticles in its outer axil; between this spine and the apex, on the same face, the style is expanded into a weak flange, provided with five or six setigerous punctures. Phallosomic plate, *p*, broadly oval, its apex very obtuse; surface of plate densely and microscopically setulose. Aedeagus, *a*, long and slender.

*Hab.*—Northern New South Wales.

Holotype, a broken ♂, Cascade, January, 1934 (F. E. Wilson); Wilson Collection.

Very different from all other members of the *annulipes* subgroup in the colouration of the legs and in the structure of the male hypopygium. Among the Australian members of this subgroup, it is closest to *Molophilus* (*Molophilus*) *gemellus* Alexander, of Victoria and Tasmania, differing conspicuously in the pattern of the wings and legs, and, especially, in the structure of the male hypopygium.

#### TASIOCERA (TASIOCERA) CASCADENSIS, n. sp.

Allied to *attenuata*; general colouration of mesonotum light brown; antennae (male) subequal in length to wing, the more proximal segments of flagellum subcylindrical, the outer ones with conspicuous basal swellings; male hypopygium with the dististyles subapical, relatively slender, narrowed outwardly, the outer margin with microscopic denticles, the lower edge before apex with two coarse teeth; phallosomic mass heavily blackened, consisting of two subequal arms, each terminating in a strong black spine.

♂. Length about 3.5 mm.; wing, 4 mm.; antenna about 4 mm.

Rostrum obscure yellow; palpi a little darker. Antennae (male) elongate, subequal to the wing, brown throughout; more basal flagellar segments subcylindrical, with long outspreading verticils that are subequal in length to the segments; outer segments shorter, with conspicuous basal swellings that taper directly into the apical stems, the verticils being grouped on the enlarged portions; longest verticils nearly twice the length of the segment. Head dark brown or brownish-grey.

Thoracic dorsum light brown, the humeral region of praescutum paler; posterior sclerites of notum somewhat darker brown. Pleura obscure yellow. Halteres broken. Legs with coxae and trochanters obscure yellow; only one leg remains, this pale with dark vestiture (broken at midlength of femur). Wings with the ground colour whitish subhyaline; macrotrichia conspicuous, dark brown, darker than the veins. Venation: Vein 2nd A relatively long, ending nearly opposite the origin of  $R_s$ , the cell correspondingly wide.

Abdomen light brown, the hypopygium concolorous. Male hypopygium (Fig. 7) with the dististyle, *d*, subterminal, the basistyle, *b*, beyond its insertion strongly constricted, thence dilated into a long oval head provided with numerous setae, some of which are unusually strong and powerful; basistyle immediately above insertion of the dististyle produced into a small obtuse tooth or flange. Dististyle slender, narrowed outwardly, the upper margin microscopically denticulate, the lower edge before apex with two coarse teeth; surface of style on distal portion with delicate setae. Phallosome,

*p*, heavily blackened, consisting of a massive structure that bears two main arms, generally similar to one another in shape and size, each terminating in a long straight black spine; upper arm with smooth margins, the lower more roughened, bearing a lateral tooth and a more or less distinct median crest that is produced into a blackened spine on its proximal portion; lateral parts of main body of phallosome produced into generally symmetrical obtuse wings.

*Hab.*—Northern New South Wales.

Holotype, ♂, Cascade, January, 1934 (F. E. Wilson); Wilson Collection.

The most similar regional species are *Tasiocera (Tasiocera) attenuata* Alexander, of Victoria and Tasmania, and *T. (T.) barringtonensis* Alexander, of New South Wales, which have the hypopygium of this same general structure but differing in all details, especially of the phallosome. It should be noted that the hypopygium is described from a microscopic mount and that the individual parts of the phallosome may assume different positions in various such mounts.

#### TASIOCERA (TASIOCERA) PROLIXA, n. sp.

General colouration chestnut-brown, the pleura more yellowish; antennae (male) about equal in length to the wing; wings with a weak brownish tinge, the veins and macrotrichia darker; male hypopygium with the dististyle terminal, at apex produced into a long slender spine, with other strong spinous developments on outer margin near apex; phallosome a broadly-flattened pale plate, the caudal margin bilobed, the edge produced into numerous pale fimbriate points.

♂. Length about 3.5 mm.; wing, 4 mm.; antenna about 4 mm.

Rostrum pale brown; palpi darker. Antennae (male) elongate, about equal in length to the wing; scape and pedicel a little paler than the blackened flagellum; basal flagellar segment very long, cylindrical, exceeding segments two to four combined; sub-basal flagellar segments very weakly binodose, these swellings indicated by concentrations of verticils; outer segments with elongate basal enlargements, provided with long crinkly verticils. Head brown.

Thoracic dorsum moderately dark chestnut-brown, much darker than the pleura. Halteres blackened. Legs with the coxae and trochanters yellowish-testaceous; remainder of legs light brown, the tarsi darker. Wings with a weak brownish tinge, the veins and macrotrichia darker. Venation: Cell 1st  $M_2$  open by atrophy of basal section of  $M_3$ ; cell 2nd A reduced to a narrow strip.

Abdomen, including hypopygium, dark brown. Male hypopygium (Fig. 6) with the dististyle, *d*, terminal, of moderate width, the apex produced into a long, very slender, pale spinous point; on outer margin before apex with various teeth or projections, including two major ones on distal third; more basad, along outer margin, with delicate setae from small raised papillae. Basistyle, *b*, with the outer setae very large and powerful, longer than the dististyle. Phallosome, *p*, very complex, appearing essentially as a broadly flattened pale to nearly hyaline plate, with the lateral margins incurved; the extensive caudal border emarginate medially, the edge produced into numerous spinous extensions to produce an irregularly fimbriated appearance; it should be emphasized that these points are not setae but direct extensions of the plate itself. Aedeagus long and slender, subtended by a median flattened pale blade that narrows to an acute point. What seems to represent a tergal development appears as a median tail-like spine, with setae at its base; in profile view, this tergal spine appears curved while in other views (as shown) it is straight.

*Hab.*—Northern New South Wales.

Holotype, ♂, Cascade, January, 1934 (F. E. Wilson); Wilson Collection.

Paratopotypes, 2 fragmentary ♂♂.

Of the rather numerous species of the genus in eastern Australia and Tasmania that have the dististyle of the male hypopygium terminal in position (including *Tasiocera ducephala* Alexander, *T. caudifera* Alexander, *T. dicksoniae* Alexander, *T. dorrigensis* Alexander, *T. gracilicornis* Skuse, *T. nodulifera* Alexander, *T. otwayensis* Alexander and *T. taylori* Alexander), the present fly is closest to *caudifera*, which has a somewhat similar hypopygium but with all details of structure distinct. In this latter fly, the

pale phallosomic plate is smooth-edged, not produced into fimbriate points, while the dististyle has the details quite distinct.

*TOXORHINA (CERATOCHEILUS) DAVIDSONI EUNGELLAE*, n. subsp.

♀. Length, excluding rostrum, about 6.5 mm.; wing, 5.5 mm.; rostrum, about 5.5 mm.

Rostrum equal in length to the wing, brown throughout. Antennae dark. Anterior vertex pale, relatively narrow.

Mesonotal praescutum with disk almost covered by three nearly confluent brown stripes, the interspaces indicated by slightly paler lines; lateral borders of sclerite broadly pale; scutellum brown, the posterior border paler; mediotergite light grey. Pleura pale, with a conspicuous dark dorsal stripe extending from the cervical region to the base of abdomen. Legs dark. Wings greyish, with broad but vague somewhat darker grey seams along cord and outer end of cell 1st  $M_2$ ; veins brown, somewhat darker in the clouded areas. Macrotrichia of anterior branch of Rs with about six trichia;  $M_1$  with trichia reduced to a single one at near two-thirds the length.

Abdominal tergites chiefly darkened, more strongly so at the incisures, the central portions of the segments paler; sternites more uniformly pale.

*Hab.*—North Queensland.

Holotype, ♀, Eungella, via Mackay, altitude 2,300 feet, March, 1929 (F. H. Taylor); returned to Taylor.

The differences from the typical form are indicated above. It seems highly probable that more material will give this fly full specific rank.



## STUDIES IN AUSTRALIAN EMBIOPTERA.

## PART VII. NEW EMBIOPTERA FROM TROPICAL AUSTRALIA.

By CONSETT DAVIS, D.Sc., Lecturer in Biology, New England University College,  
Armidale.

(Fourteen Text-figures.)

[Read 29th March, 1944.]

## Family OLIGOTOMIDAE Enderlein 1909.

*Zool. Anz.*, 35: 190.

## Genus OLIGOTOMA Westwood 1837.

*Trans. Linn. Soc. Lond., Zool.*, 17: 373 (as subgenus of *Embia* Latreille. Raised to generic rank, Burmeister, 1839, *Handbuch der Entomologie*, 2: 770). Genotype: *Oligotoma saundersii* Westwood 1837, l.c.

## OLIGOTOMA GURNEYI Froggatt 1904.

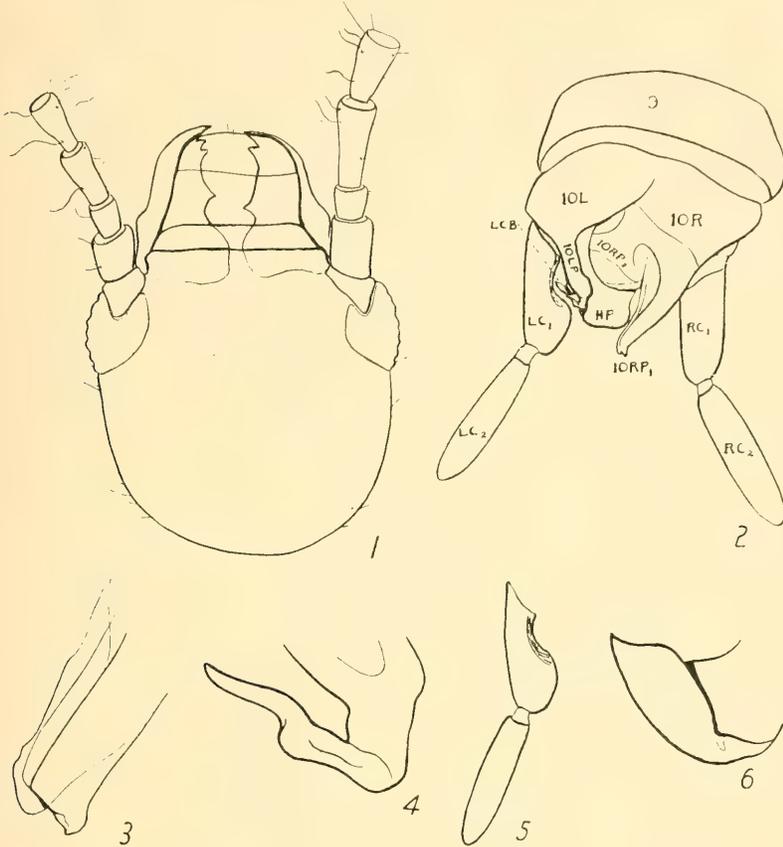
*Proc. Linn. Soc. N.S.W.*, 29: 672; Davis, 1936, *ibid.*, 61: 231. Figs. 1, 11, 18, 25, 32.

## OLIGOTOMA GURNEYI REMOTA, n. subsp. Figs. 1-6.

♂. Length 5.3 mm.; head 1.0 mm. × 0.6 mm.; forewing 3.2 mm. × 0.6 mm.; hindwing 2.6 mm. × 0.6 mm. Colour: Head dark brown, eyes black, body sclerites golden-brown, wings with  $R_1$  and  $Cu_1$  (and its continuation  $Cu_{1b}$ ) golden-brown, all veins or traces of veins bordered by pale brown bands. Head (Fig. 1) almost semi-circular in outline behind the eyes, which are not prominent. Antennae incomplete (length 2.0 mm. for 10 segments), sensory hairs sparse, fine, relatively long, undulant. Mandibles with medial concavity of inner face less defined than in type subspecies. Thorax normal; wings with distribution of veins or traces of veins as throughout the genus, only  $Sc$ ,  $R_1$ ,  $Cu_1$  (and its continuation  $Cu_{1b}$ ) and 1A definite,  $R_s$  (and its continuation  $R_{2+3}$ ) weak, remaining veins represented merely by bordering pigment-bands and, in the forewing, by rows of macrotrichia; even the latter are absent in the hindwings. No cross-veins present. Hind tarsi normal for the genus, i.e., without medial ventral basitarsal bladder. Terminalia (Figs. 2-6) agreeing in general plan with the type subspecies. Posterior process of right hemitergite ( $10RP_1$ ) terminally bifid, the outer tooth being in the form of a small, obtuse, slightly curved dorsal hook (Fig. 3). Inner process of right hemitergite ( $10RP_2$ ) rather broad and irregular. Process of left hemitergite ( $10LP$ ) distinctive, basally rather irregular, distally suddenly narrowed and curved downwards and to the left through about  $135^\circ$  to form a strongly-chitinized hook (Fig. 4), irregularly tapered, terminally sinuous and acute. First segment of left cercus ( $LC_1$ ) with a prominent smooth swelling occupying most of the distal half of the inner face; basad to this the inner face is hardened, flattened in the vertical plane, devoid of setae, and slightly excavate (Fig. 5). Left cercus-basipodite (LCB) fused to left side of hypandrium, free distal end curved and folded upwards and slightly forwards, projecting to the left to engage the hardened basal part of the inner face of the left cercus, and terminally subacute (Fig. 6). Process of hypandrium (HP) terminally slightly expanded as a smooth tongue-like plate.

♀. Length 5.9 mm.; head 0.9 mm. × 0.6 mm. Colour pale brown (? not fully melanized after ecdysis), eyes black, head with slightly darker symmetrical tracery.

*Locality*.—Barred Creek Well, about 20 miles north of Broome, north-west Australia, 20.vii.43, collected by the author in web among fallen leaves and bark against the bases of white-gums, in the Pindan formation. Holotype ♂, allotype ♀, the only specimens secured, Macleay Museum, University of Sydney.



Figs. 1-6.—*Oligotoma gurneyi remota*, n. subsp., holotype ♂. 1. Head from above,  $\times 60$ , outline of mandibles shown. 2. Terminalia from above,  $\times 60$ . 3. Outer process of right hemitergite from above,  $\times 355$ . 4. End of process of left hemitergite from above,  $\times 355$ . 5. Left cercus from above and to the right,  $\times 60$ . 6. Free end of left cercus-basipodite from above,  $\times 355$ .

All figures based on camera lucida outlines. Setae omitted except in Fig. 1.

9, ninth abdominal tergite; 10L, 10R, left and right hemitergites of tenth abdominal segment; 10RP<sub>1</sub>, 10RP<sub>2</sub>, outer (posterior) and inner processes of 10R respectively; 10LP, process of 10L; LC<sub>1</sub>, LC<sub>2</sub>, RC<sub>1</sub>, RC<sub>2</sub>, first and second segments of left and right cerci respectively; LC, one-segmented left cercus; LCB, left cercus-basipodite; H, hypandrium; HP, process of H.

The adults of both sexes are the smallest Oligotomidae known from Australia. Structurally, the male is furthest removed of all subspecies of *O. gurneyi*; comparison with the males of other subspecies is summarized in Table 1.

The structure and distribution of these representatives of *O. gurneyi* have been discussed earlier (Davis, 1936, pp. 231-241; 1938, pp. 252-254; 1940, pp. 158-160, and Map 1; 1943). Geographically, the closest record is that from Lalla Rookh Station, some 300 miles south-west of the type locality of *O. gurneyi remota*; the unnamed variant from this locality also occurs at Hermannsburg, some 800 miles south-east of Broome, while Daly Waters, type locality of *O. gurneyi subclavata*, is some 700 miles east of the type locality of *O. gurneyi remota*. No males have yet been secured from any intermediate points. One female and two larvae, unidentifiable, but with tarsi as

TABLE I.  
*Variation in the Subspecies (Geographic Races) of Oligotoma gurneyi Frogg.*

Subspecies.	Range.	Size.	10RP.	10LP.	LC.	LCB.	HP.
<i>gurneyi</i> . . . . .	N.S.W. (Sydney-Nyngan) to eastern Victoria and Tasmania.	Small to rather large.	Termination tapered.	Hook normal.	Subterminal angular inward projection.	End tapered, sub-obtuse.	Tapered.
<i>gurneyi-centralis</i> . . . . .	Western Victoria (Lady Julia Percy I.) to south-eastern parts of South Australia (Lucindale-Adelaide).	Medium to rather large.	" "	" "	" "	End flat, rounded, upcurved.	" "
<i>centralis</i> . . . . .	Central Australia (Alice Springs - Macdonnell Ranges).	Rather large.	Termination bi-dentate.	" "	Prominent inward protuberance one-third length from end.	" "	" "
<i>gurneyi-centralis-subclavata</i> .	South Queensland (Chinchilla).	" "	" "	" "	Subterminal angular inward projection.	End tapered, sub-obtuse.	" "
<i>subclavata</i> . . . . .	North Australia (Anthony's Lagoons-Daly Waters).	Small.	" "	" "	Slight smooth dilatation in distal third.	End flat, rounded, upcurved.	" "
<i>subclavata-centralis-spinulosa</i> .	Central Australia (Hermannsburg) to north-west Australia (Lalla Rookh, near Port Headland).	Rather large.	" "	Hook rather slender.	Very slight smooth dilatation in distal half.	End flat, obtuse, upcurved.	" "
<i>spinulosa</i> . . . . .	Western Australia latitudes 26° S. to 50° S. (Morgan's-Lake Violet-Annean - Beletle-Geraldton).	Medium to large.	" "	Hook slender, sinuous.	Strong angular terminal inward projection.	End acute, spin- escent, directed outwards.	" "
<i>remota</i> . . . . .	Far north-west Australia.	Very small.	" "	Hook strong, irregularly tapered.	Strong but smooth inward dilatation occupying distal half.	End flat, upcurved, directed to left, subacute.	Terminally slightly expanded, linguiform.

for the genus *Oligotoma*, were secured some 120 miles east of Broome (Duraban Pool, Fitzroy River, near Mt. Anderson, 27.vi.43: under decaying logs on open river flats, *Bauhinia Cunninghamii* Association), the size and colour of the female (length 14.2 mm.; head 1.9 mm.  $\times$  1.5 mm.; colour of sclerites dark red-brown, slightly paler ventrally) suggesting that it is not very closely related to *O. gurneyi remota*. A further 120 miles to the east, in a similar situation on the banks of the Margaret River at Fossil Downs, characteristic web was found (20.vi.43), the insects apparently having been killed or forced to migrate elsewhere by the dry season. Generally speaking, members of the Order are very rare in the north-west and Kimberley districts of Western Australia.

Family NOTOLIGOTOMIDAE Davis 1940.

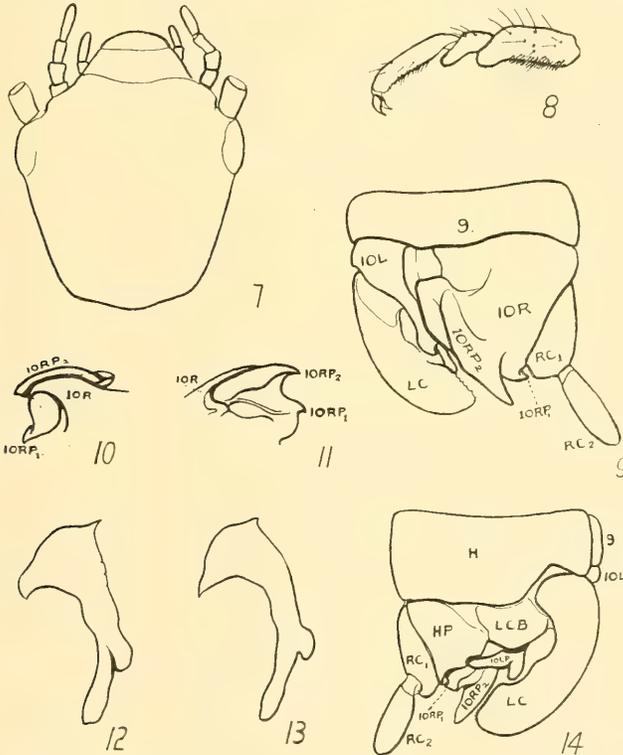
*Ann. Ent. Soc. Amer.*, 33 (4): 681.

Genus METOLIGOTOMA Davis 1936.

*Proc. Linn. Soc. N.S.W.*, 61: 248. Genotype: *Metoligotoma reducta* Davis 1936, l.c.

METOLIGOTOMA NODOSA, n. sp. Figs. 7-14.

♂. Length 6.5-11.5 mm.; head 1.5-2.3 mm.  $\times$  1.1-1.7 mm. Colour: Dorsally black, shiny, with faint bronze sheen (alcoholic specimen under binocular; dull black in life to the naked eye); ventrally dark brown, anterior abdominal sternites paler medially. Segments of legs dark brown, of antennae golden-brown. Inter-segmental membranes



Figs. 7-14.—*Metoligotoma nodosa*, n. sp., ♂ (Figs. 7-9 and 14 from the holotype, remainder from paratypes). 7. Head from above,  $\times$  19. 8. Hind tarsus, lateral view,  $\times$  28. 9. Terminalia from above,  $\times$  28. 10. Processes of right hemitergite of tenth abdominal segment; hemitergite separated from rest of terminalia and viewed from the right,  $\times$  22. 11. The same, from the left,  $\times$  22. 12. Left hemitergite of tenth abdominal segment from above,  $\times$  28. 13. The same, from above and to the left,  $\times$  28. 14. Terminalia from below and slightly to the left,  $\times$  28.

All figures based on camera lucida outlines. Setae omitted except in Fig. 8. For explanation of lettering see below Figs. 1-6.

cream. Head (Fig. 7) with sides straight, strongly converging from eyes to posterior limit. Antennae up to 4.1 mm. long, with up to 20 segments; small specimens with apparently complete antennae of 18 segments, length 2.7 mm. Hind tarsi with a vesicle at the distal end of the plantar surface of the first segment, remainder of surface covered with stiff setae (Fig. 8). In this respect, the species, together with *M. rileyi* Davis (1940, p. 155), differs from all others in the genus. Terminalia (Figs. 9-14) agreeing in general plan with other species of the genus; right hemitergite with its posterior and inner processes (10RP<sub>1</sub>, 10RP<sub>2</sub>; Figs. 10, 11) formed so that there is a distal concavity between them, into which the indrawn left cercus fits; the posterior process is short, thick, irregularly tapered, directed downwards, and terminally subacute, while the inner process is produced backwards to a smoothly-tapered process, subacute in lateral aspect. Antero-medial extension of 10RP<sub>2</sub> pale, membranous, subrectangular. Process of left hemitergite (10LP; Figs. 12-13) long, finger-like, terminally curved down to rest against distal edge of left cercus-basipodite; at half its length, 10LP gives off a rounded nodule, soft but fully melanized, and directed upwards and backwards. The indrawn left cercus fits into the angle between this nodule and the main process. Left cercus (LC) one-segmented, outer margin strongly convex, almost semi-circular, inner margin medially excavate, distally formed into a straight echinulate edge; medial concavity of inner face of cercus with a very slight, faintly echinulate swelling. Left cercus-basipodite (LCB) a large plate, its distal (free) margin barely convex, without process. Process of hypandrium (HP) terminally elongate-tapered, curved upwards beside base of first segment of right cercus. Fifteen males examined.

♀. Length 13.1-15.3 mm.; head 1.7-1.9 mm. × 1.4-1.5 mm. Colour: Head and pronotum orange-brown with chocolate markings; remaining tergites chocolate-brown with paler flecks; abdominal pleurites and sternites pale brown, abdominal sternites, except viii-x, merging to cream at centre. Segments of legs and antennae pale chocolate-brown; inter-segmental membranes cream. Antennae up to 3.0 mm., with 18 segments. Tarsi as in the male. Six females examined.

*Locality*.—Ravenshoe—Mt. Garnett Road, 10 miles from Ravenshoe, N. Queensland, on rocky slopes overlooking The Millstream, among dead leaves (especially of *Pipturus argenteus* Wedd.) in low-grade rain-forest; collected by the author, 20.iii.43, immature, males maturing in culture, April-May, females March-September. Holotype ♂ and allotype ♀, Macleay Museum, University of Sydney.

This species agrees with the only other member of the genus recorded from North Queensland (*M. rileyi* Davis, from Townsville) in the exceptional tarsal structure, but differs considerably from it in details of the terminalia, only the right hemitergite showing any close similarity. *M. nodosa* differs from all other members of the genus (for that matter, all members of the Order) in possessing a smooth, approximately spherical nodule as lateral lobe of the process of the left hemitergite, 10LP.

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A NEW SPECIES OF THE GENUS *ANOPHELES* FROM NORTHERN AUSTRALIA  
(DIPTERA, CULICIDAE).

By D. J. LEE, B.Sc., Department of Zoology, University of Sydney.

(Nine Text-figures.)

[Read 26th April, 1944.]

*ANOPHELES* (*ANOPHELES*) *POWELLI*, n. sp.

This new species from northern Australia is a small brown concolorous Anopheline, in appearance suggesting a *Culex*. In the Australasian Region it is only to be confused with *A. stigmaticus* Skuse and *A. aitkenii* James (and species closely related to the latter). From these it is most readily distinguished in the female by its long slender proboscis, from *A. stigmaticus* by its uniformly dark brown legs and from *A. aitkenii* by the narrow elongate outstanding scales on the wing veins. The bifid inner anterior clypeals of the larva immediately distinguish this stage from *A. stigmaticus*, and the simple, thickened, outer clypeals from *A. aitkenii*.

DESCRIPTION.

*Female.*

*Head.* The integument is dark brown with a greyish bloom; rather sparsely covered with exceedingly narrow, elongate, black, upright-forked scales. No recumbent scales are present nor are there any scales projecting forward between the eyes, only black bristles. The pedicel and basal two-thirds of the first flagellar segment of the antennae are light brown, the rest brown with brown clothing hairs and dark brown verticillate hairs. The first flagellar segment is noticeably longer than the second (ratio 5:3), the succeeding ones subequal but increasing in length gradually to the apex, the apical segment being twice the length of the second. The total length of the antennae is scarcely more than half that of the proboscis. The clypeus is brown to dark brown, bare and pruinulent. The palpi are as long as the proboscis, uniformly dark brown scaled. The proboscis is similarly adorned, noticeably elongate with yellowish labella. The neck is prominent.

*Thorax.* The integument is shiny, dark brown to reddish-brown; certain parts may appear yellowish, particularly the anterior lateral areas of the scutum, but these are not constant. There are no scales present on any part of the thorax. The scutum bears three longitudinal lines of dark brown or black bristles, the central one median, the lateral ones midway between the median line and the lateral margins. There are also a few irregular lateral bristles anteriorly, and a pronounced group just before and above the wing base. The scutellum is uniformly rounded, brown, sometimes yellowish, with a prominent fringe of dark brown border bristles; the postnotum is brown and bare. There are few bristles on the pleurae. The pronotal lobes carry eight or nine dark brown bristles, the propleuron one, and the pronotum is bare. There are no spiracular bristles. On the sternopleuron there are one or two bristles on the posterior margin near the upper margin of the meron, one upper sternopleural bristle and a reduced pre-alar group of no more than one bristle. The mesepimeron has three or four sub-alar bristles. The halteres are pale-stemmed with a dark scaled knob.

*Legs.* The coxae are somewhat lighter than the pleurae and carry bristles but no scales. The femora, tibiae and tarsi of all legs are uniformly dark brown scaled above and below.

*Wings.* (Fig. 2.) These are uniformly dark brown scaled, the scaling dense on C, R<sub>1</sub> and Cu. The outstanding scales, particularly on the distal half of the wing, are distinctly narrow and elongate. The wing fringe is uniformly brownish. The upper fork cell is longer and narrower than the lower, its base nearer the wing base. The upper cell is slightly longer than its stem (one-fifth) and the lower slightly shorter (one-sixth). There is no dark cloud on the wing membrane.

*Abdomen.* The abdomen is brown, shining, devoid of scales but covered with brown hairs.

#### *Male.*

The male resembles the female except that the palpi are as long as the proboscis exclusive of the labella and the ultimate and penultimate segments are expanded into a distinct club which carries numerous hairs as well as scales. The antennae are plumose, with dense brown verticillate hairs. The proximal flagellar segments are subequal, the distal two lengthened, the terminal one being twice as long as the basal flagellar segments, the subterminal four times as long.

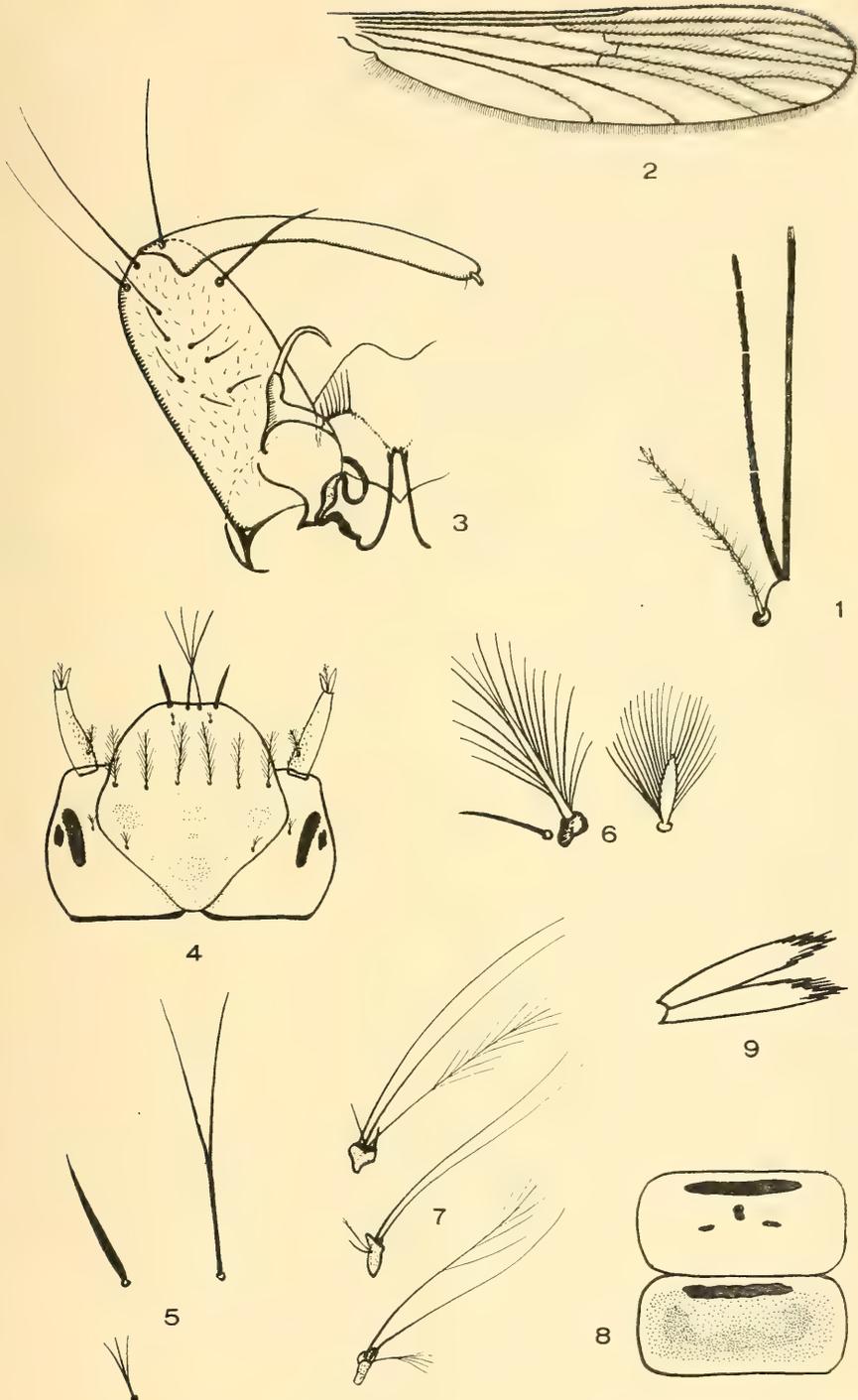
*Genitalia.* (Fig. 3.) The coxites are sparsely hairy and without scales. They are approximately cylindrical and about twice as long as broad. The claspers are narrow, very slightly expanded apically, about one-eighth longer than the coxites, bearing a terminal peg-like tooth and a few minute hairs. The coxite bears an internal subapical bristle which is slightly longer than the width of the coxite. A single stout curved spine in the position of the parabasal spines arises from a pronounced basal lobe which is prolonged into a distinct tubercle about one-third as long as the spine it bears. (This is similar to *A. stigmaticus* but considerably more strongly developed.) The harpagones are not noticeably separated into dorsal and ventral lobes, are finely hairy, and bear a continuous line of about nine short fine spines each arising from a small boss. The phallosome is smooth and terminates apically in a number of very short, inconspicuous spines.

#### *Larva.* (Figs. 4-9.)

The larva is small and pale, resembling in many respects those of both *A. stigmaticus* and *A. aitkenii*.

*Head.* The head is pale, often with darkened spots as illustrated in Fig. 4. The antennae are short, rather squat, spicular, particularly on the inner side, with a small seven- or eight-branched hair arising internally near the base. The inner anterior clypeals are long, crossed, usually bifid, though occasionally one is trifid; the branches arise at from one-third to one-half the length from the base. The outer anterior clypeals are simple, noticeably thickened and about half as long as the inners. The posterior clypeals are very fine, usually trifid (but vary from two- to four-branched), not reaching to the level of the bases of the outer clypeals. The frontal hairs are short and plumose, the innermost pair are longest, but even these scarcely reach the bases of the posterior clypeals. The inner suturals are trifid, the outer suturals usually four-branched and situated anterior to the inners. The ocular hair is five-branched.

*Thorax.* The inner shoulder hair (hair 1 of the prothorax) has about 30 branches arising from a thick, flattened shaft. The centre shoulder hair (hair 2) arises from a distinct boss, is plumose and with the shaft somewhat thickened; in length it is scarcely twice as long as hair 1. The outer shoulder hair is simple and slightly thickened. Hair 4 is about half as long again as 2, arising also from a distinct boss with thickened stem; it is sparsely plumose with prominent branches. Hair 5 is about as long as 4, plumose, but the branches are short and fine and its shaft is thickened. Hair 6 is long and simple and arises with 5 from the same strong boss. In all, the prothoracic group of hairs is considerably different from most other Anophelines. On the metathorax a reduced palmate tuft is present consisting of about 20 leaflets each of which is recognizably flattened. Of the pleural hairs, the pro-pleural group comprises three long hairs, two of which are simple and the third plumose. The meso-pleural group has two long simple hairs, and of the meta-pleural group one long hair is plumose.



Figs. 1-9.—*Anopheles (Anopheles) powelli*, n. sp. 1. Proboscis, palp and antenna of ♀, × 45. 2. Wing of ♀, × 25. 3. Male genitalia, × 225. 4. Head of larva, × 62. 5. Details of clypeal hairs, × 225. 6. Shoulder hairs, × 225. 7. Pleural hairs, × 65. 8. Details of chitinizations of abdominal segments VII and VIII, × 70. 9. Detail of leaflets of abdominal palmate tufts, × 500.

*Abdomen.* A palmate tuft similar to that of the metathoracic one is present on abdominal segment I and fully-developed palmate tufts occur on segments II-VII. The fan leaves are unusual in being strongly frayed before the apex. The chitinizations of the dorsal surface of the abdominal segments consist, on segments I to VII of an anterior, narrow-elliptical transverse plate, behind which is situated a very small laterally constricted longitudinal plate; behind this again are two very small round spots situated one on either side of the mid-line. On segment VIII the anterior plate is surrounded by a secondary chitinization almost entirely covering the dorsal part of the segment. The lateral hairs of the first three abdominal segments are noticeably long and strongly plumose. The pecten consists of approximately 14 teeth, the outer three or four at either end being considerably longer than the majority of the intervening ones. The saddle hair is long and divided apically into four or five branches.

*Type locality:* Adelaide River (Northern Territory of Australia), 1943 (O. W. Powell).

*Types:* Holotype male, allotype female and their associated larval skins together with a paratype series, also with their larval skins from the same locality and collection are located in the Museum of the Council for Scientific and Industrial Research, Canberra, A.C.T. Representative specimens from all recorded localities have also been lodged in the same Museum.

*Distribution.*—So far only recorded from northern Australia.

Queensland: Jacky Jacky, xi.42 (I. M. Mackerras). Northern Territory: Marara Swamp, near Darwin; Adelaide River, iii.43 (O. W. Powell); 8 miles S. of Adelaide River, ii.43, iii.43; Adelaide River, iii.43 (A. R. Woodhill); 10 miles N. of Pine Creek, iii.43 (Hegener); Groote Eylandt, ix.43 (J. Henry).

*Biology.* Powell and Woodhill found this species breeding in shallow overgrown swampy pools shaded by tall grass. Adults were taken in mosquito nets, some with blood in their abdomens, but it is unlikely that this species will be shown to have any importance as a vector of disease.

#### *Comparative Notes.*

In a series of 15 specimens of *A. powelli* from all recorded localities, the average ratio of proboscis to fore-tibia was 1.19, the range being from 1.12 to 1.28. A similar series of 15 specimens of *A. stigmaticus* from Sydney and Cairns gave an average ratio of 0.88 with a range of from 0.79 to 0.95. One specimen of *A. aitkenii* from Ceram gave a ratio of 0.83 for these structures. For the males the ratios were *A. powelli* 1.24 (range 1.20 to 1.27 in five specimens), *A. stigmaticus* 1.22 (range 1.15 to 1.27 in five specimens), and *A. aitkenii* 1.19 in one specimen. Hence it is only in the female that the proboscis character is of diagnostic value.

A similar relationship of the length of the proboscis to other structures is noticeable in *A. powelli* so that casual examination suggests that this structure is unusually long. The ratio of length of proboscis to length of antenna is 1.8 in *A. powelli* and 1.1 in *A. stigmaticus*.

The genitalia of the male, although with undoubted similarity to *A. stigmaticus*, are nevertheless distinct in the considerably reduced development of the claspette spines and the very short processes at the apex of the phallosome. For the same reasons the new species cannot be included in *A. corethroides* Theobald (see Edwards' description of the genitalia of Theobald's type in *Bull. ent. Res.*, xii, 352). The single spine at the base of the coxite is in strong contrast to the pair of parbasal spines found on each coxite of *A. aitkenii*.

In larval characters *A. powelli* is somewhat intermediate between *A. stigmaticus* and *A. aitkenii*, but the following tabulation will clarify the distinctions.

*Comparison of Larval Characters.*

Character.	<i>A. powelli</i> , n.sp.	<i>A. stigmaticus</i> Sk.	<i>A. aitkenii</i> James.
Inner anterior clypeals.	Bifid.	Simple.	Simple to plumose in different forms and varieties.
Outer anterior clypeals.	Simple, thickened, half the length of the inners.	Simple, thickened, at least half the length of the inners.	Branched, about half the length of the inners ( <i>A. aitkenii</i> ) or very short and simple ( <i>A. palmatus</i> and <i>A. insulæ-florum</i> ).
Inner shoulder hair.	Shaft broadened.	Shaft not broadened.	Shaft broadened.
Pro-pleural hairs.	One long hair plumose.	One long hair may be plumose, but usually all three are simple.	One long hair branched apically.
Meso-pleural hairs.	Both long hairs simple.	Both long hairs simple.	Both long hairs simple (in var. <i>bengalensis</i> one is bifid).
Meta-pleural hairs.	One long hair plumose.	At most one long hair bifid or trifid.	At most one long hair is apically branched.
Fan leaves.	Appearing torn apically.	Smooth.	With normal serrations.
Pecten.	About 14 spines.	About 20 spines.	About 11 spines.



originated from the absorption of petroleum by clay, followed by the interaction of hydrocarbon acids with silicates of alumina, which gave a solid substance, torbanite. Dixon (see Carne, 1903) pointed out the impossibility, in the case of richest torbanites, of saturating less than 6% of mineral matter with over 90% of hydrocarbons. Wilkinson (1880) believed that the organic bodies in Australian torbanite were lycopodian spores.

An important development in research on the origin of torbanite took place towards the close of the nineteenth century, when David (1889) first suggested the possibility of an algal origin. He published a paper discussing the means by which spore material could have accumulated in sufficient quantities to form torbanite, but added an appendix describing structures which, he considered, bore a resemblance to algae of the Volvocineae; he suggested that the organic matter might have been formed from an alga. Soon after David's suggestion, the subject was taken up by two French scientists, Bertrand (C. E.) and Renault, who developed the algal theory and published a number of papers (1892 to 1901) describing the algae in torbanites from different parts of the world. They observed, in French and Scottish torbanites, masses of thick-walled cells, closely packed and radially arranged in the algal colonies, while in Australian torbanites they described an envelope, built up of a single layer of cells enclosing a large, central cavity. This difference in morphology was believed to be due to different genera of algae, and the generic names *Pila* and *Reinschia* were given to the two forms, respectively.

Seward (1898) supported the algal theory; but the results of Bertrand and Renault were not generally accepted—their evidence lacking conviction with regard to cell structure and means by which the algae could be preserved to form torbanite. Many workers still believed that the organic bodies were spores of vascular plants. Jeffery elaborated the spore theory in a number of papers (1909–1924), dealing mainly with the Kentucky torbanite, in which the algal cell structure is poorly shown; but he claimed that the spore theory applied to all torbanites. He described the compact bodies in the French and Scottish torbanites as microspores, and the large bodies possessing central cavities—typical of Australian types—as macrospores. The fuzzy, indefinite margins and spongy appearance, exhibited by the bodies in thin sections, were, he explained, oblique sections of rough spore coats.

Conacher (1917) believed that the organic bodies were particles of resin; the internal cell structures were conchoidal cracks formed by shrinkage; and the cavities were gas bubbles. He first observed certain cone-in-cone structures within the bodies and a pit on the surface at the base of each series of cones. These were eventually shown by Temperley (1936) to be important features in the structure of the algal colony, but Conacher attributed them to symmetrical shrinkage cracks. Cunningham-Craig (1916, 1919) attempted to revive old theories, involving the consolidation of liquid hydrocarbons, by suggesting that the organic bodies were inspissated petroleum residues. His views were not accepted by other investigators.

Zalessky (1914 to 1926) studied the Russian torbanites, and recorded evidence in support of the algal theory. Apparently he was the first to recognize the similarity between the fossil alga of torbanite and the living type *Botryococcus Braunii*. He described algal deposits on the shores of Lake Balkhash, closely resembling coorongite from South Australia, and attributed both to *Botryococcus*. He suggested that similar material might have been the original organic matter of torbanite, but still held to the belief that the algal deposits had been impregnated with liquid hydrocarbons. Zalessky also described algae in several of the Russian torbanites, emphasizing certain resemblances to living forms.

The next valuable contribution to the algal theory was made by Thiessen (1925), when he published his views concerning the relations between coorongite and torbanite. He amplified Zalessky's observations on the similarity between the fossil alga and *Botryococcus*, and described the peculiar composition and decay-resisting properties of coorongite. He explained that the cell walls of the alga were responsible for the particular nature of both coorongite and torbanite, and showed that the latter could be derived from algae, without the addition of any extraneous hydrocarbons. In later work, Thiessen used the algal theory as a basis for differentiating between torbanite and other coals.

White (1926, 1930) accepted the views of Thiessen, and described algal sapropel as the peat-stage of torbanite. The earlier work of Bertrand (C. E.) and Renault was followed up by Bertrand (P.) (1927, 1930), who accepted the similarity between *Pila* and the Botryococcaceae, but still maintained that *Reinschia* belonged to the Volvocaceae. He also described the grouping of cells in the fossil colonies—a feature treated in greater detail by Temperley in more recent work.

The algal theory was more or less generally accepted by 1930; but some doubt was still expressed, as evidence had not been established to prove, beyond all doubt, that the structures in the organic bodies were algal. This was due to the fact that the detailed morphology of the fossil alga and the living form, which it closely resembles, had not been fully and systematically worked out. This remained to be accomplished by Blackburn and Temperley. The living alga, *Botryococcus Braunii*, was studied and described by Blackburn (1936); and the structures in the organic bodies of torbanite were described by Temperley (1936), and explained by comparison with those of the living alga. The results of this work provide convincing evidence that the organic bodies in torbanite are fossil colonies of an alga closely related to the living type, *Botryococcus Braunii*. Their conclusions, regarding the similarity between the two, are based on the following common characteristics:

1. Each consists of a framework showing, in its structure, evidence that it was built up from the secretions of a colony of cells.
2. Each has a cone-in-cone or dome-in-dome structure, which could only be built up by each new cell secreting a complete new cup after each process of cell division, and by each old cell remaining in the structure of the colony—there playing the part of binding the cells together.
3. Each has a globular form when small.
4. Each shows a certain degree of polymorphism when large. This polymorphism, in each case, involves an alternative form, in which the cells are more closely packed and no longer arranged in groups, while, at the same time, the amount of secreted matter at the centre of the colony is very small.
5. Each consists of secreted material with properties which include high resistance to decay, and yield a paraffin on distillation.

#### *General Morphology of the Living Alga, Botryococcus Braunii.*

It is not intended that this section of the work should make any biological contribution to the nature of the alga found in torbanite. The main object is to show that the New South Wales torbanites are composed of the fossil remains of an alga closely related to *Botryococcus Braunii*, and to explain the structures of the organic bodies in terms of the morphology of this alga. The following, brief description of *Botryococcus*, based on the work of Temperley and Blackburn, is included as a necessary preliminary to the interpretation of the structures which can be recognized in the organic bodies of all the torbanites of the New South Wales deposits.

The alga consists of a single, pear-shaped cell enclosed within a cellulose wall, and covered, at the large end, by a cap of cellulosic and pectic substances. The cell wall is surrounded by a cuticular thimble possessing a small opening which allows the cap at the large end of the cell to communicate with the exterior. Excess fatty substances, secreted by the cell, form a thick cup-like structure round the thimble (Fig. 1A). The cup and thimble consist of firm substances possessing a large degree of elasticity. The cell reproduces by longitudinal division, and each daughter-cell secretes a new cup within the original thimble and cup, which become extended to accommodate the new cell (Fig. 1B). The daughter-cells protrude slightly from the old cup, which binds them together, and they divide in a manner similar to the original cell, producing four cells, complete with thimbles and caps, and arranged in two pairs within the original cup (Fig. 1C). Cell division continues building up a globular colony; the old, fatty cups fuse to form the matrix of the colony; and the old, cuticular thimbles form a kind of supporting skeleton. A layer of pectic mucilage, derived from the cell caps, forms around the colony, and when 40 to 60 cells are formed, the colony either branches or breaks down to form several colonies loosely connected by threads. A large mass of

cells is formed in this way, representing a compound colony, which is the algal body seen in thin sections of torbanite.

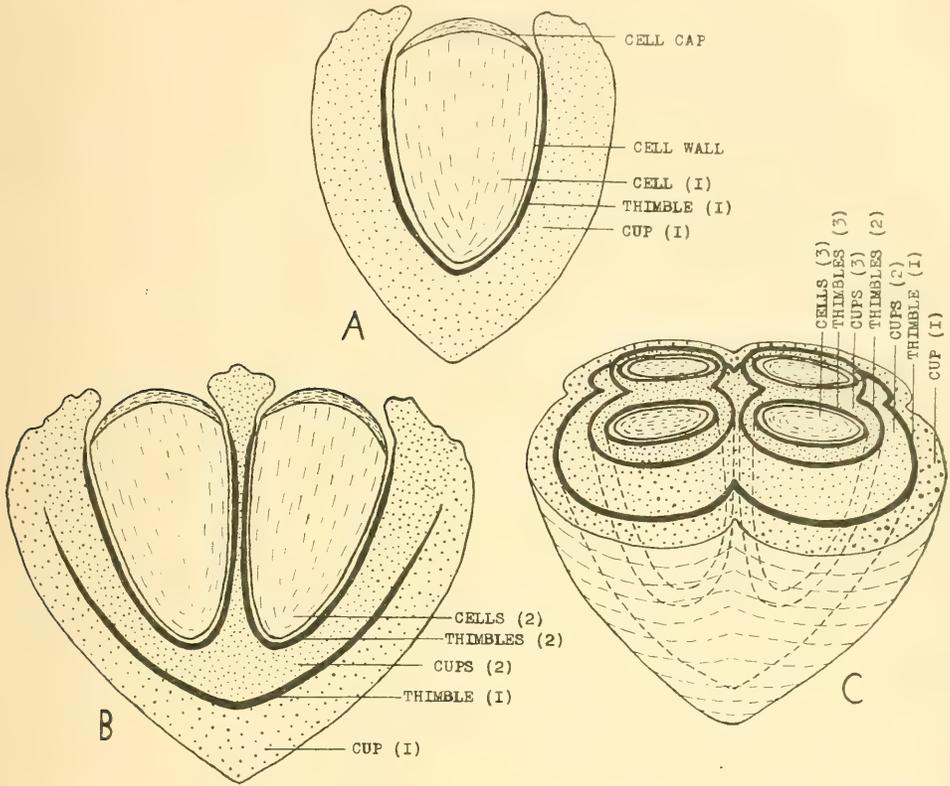


Fig. 1.—Diagrammatic illustration of reproduction and colonial structures in *Botryococcus Braunii*. (After Blackburn.) ( $\times 2,000$ .) A, Single cell; B, After division to form two cells; C, After division to form four cells.

Structural modification in the compound colonies gives rise to the different forms of algal bodies originally described as *Pila* and *Reinschia*. This is determined by the way in which development occurs after the simple colony has reached its maximum size. Branching in all directions and the fusing of old cups cementing the branches together produces a solid botryoidal mass. This is the compact form of compound colony found in the Scottish and Autun torbanites and referred to as *Pila*. Development of the simple, globular colony may proceed in such a way that new groups of cells are closely packed round a central cavity. This type of compound colony, when flattened by compression, gives rise to the disc-shaped, algal body containing a collapsed central cavity, which is typical of Australian torbanites, and which is referred to as *Reinschia*.

#### *Interpretation of the Structures in the Organic Bodies of Torbanite.*

The micro-constitution of torbanite has been described in a previous paper (Dulhunty, 1939a), and it has been emphasized that all the New South Wales torbanites exhibit a typical micro-structure in thin sections. This consists of yellow, translucent, disc-shaped, organic bodies lying parallel to the bedding planes, and separated by thin films of opaque, inorganic matrix which forms a kind of skeleton. In some high-grade torbanites the organic bodies are packed so closely that the matrix occurs only as isolated fragments. The organic bodies consist of gelosite and retinosite, and their internal structures may be correlated with the morphology of *Botryococcus Braunii* in the following manner:

In the living colonies, the cups, secreted by the cells, form the matrix; and the thimbles, marking the positions of the old cells, form a supporting skeleton. When the colonies die, the cups and thimbles form a tough, rubbery mass, resistant to decay and remaining long after the death and disintegration of the algal cells. This material is preserved to form the algal bodies of torbanite; and the internal structures are the thimbles or skeletons of the original colonies. The thimbles give a true picture of the structure of the colonies, each cell having possessed a thimble, held in position by matrix formed from the old cups. In vertical sections, the bodies exhibit a central, longitudinal dark band of variable width (Plate i, A), representing the collapsed central cavity of colonies which belong to the hollow, spherical (or *Reinschia*) form. The apparent absence of a central cavity, seen in some sections, may mean that the colony belongs to the compact *Pila* form, but, in most cases, it is due to the section passing through the margin of the colony. The central cavities are rarely seen in horizontal sections which are parallel to the plane occupied by the flattened cavities. The bodies frequently show a series of bulges, arranged more or less regularly round their margins (Plate i, B), giving rise, in some cases, to a botryoidal appearance. The bulges represent simple colonies, fused together to form compound colonies.

The arrangement of cells and other detailed structures, within the algal bodies, are revealed by high magnification (250–500 diameters), and commonly consist of rectangular lines, oval shapes, funnel-shaped structures, cones and radiating or branching lines—depending on the position and direction of the section. The rectangular system of lines, usually seen in a horizontal section above or below the central cavity, is produced by closely packed cells having divided and redivided in two directions at right angles—each producing four daughter-cells. These are situated within the original mother-cell cups, which have been extended and compelled to assume a rectangular shape, owing to the proximity of neighbouring cups (Fig. 2B). The oval shapes (Plate i, C) appear in both vertical and horizontal sections which pass obliquely through a series of cells (Section m–n, Fig. 2A), in which the new cups are complete and well preserved. Cone-sections or funnel-shaped structures are particularly common (Plate i, D), arising from sections in the direction o–p (Fig. 2A). They represent longitudinal sections of the cell thimbles (Fig. 2C) and may appear in vertical sections

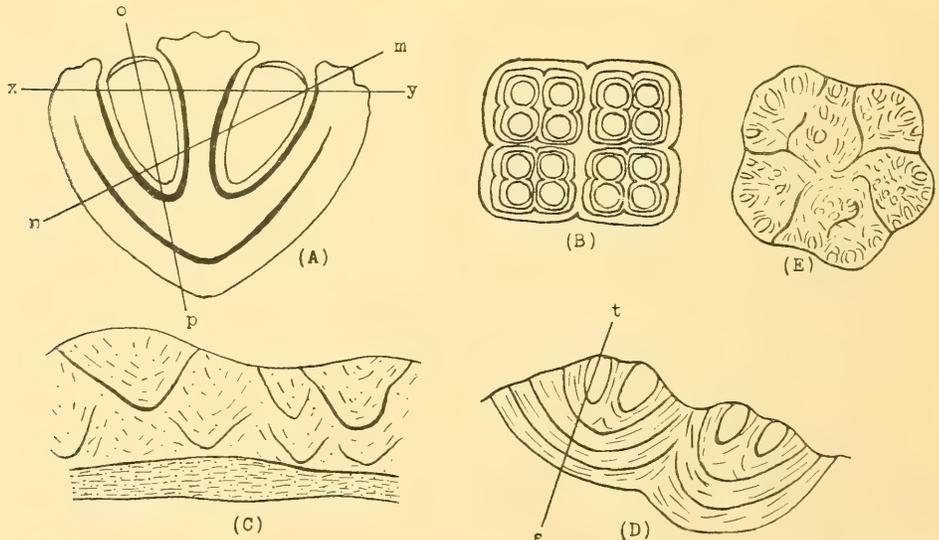


Fig. 2.—Diagrammatic illustration of algal structures in gelosite and retinosite. A, A pair of cells with cups and thimbles ( $\times 1,200$ ); B, Cells in groups of four, giving rise to rectangular arrangement seen in horizontal sections ( $\times 420$ ); C, Portion of compound colony showing funnel-shaped structures representing old thimbles ( $\times 580$ ); D, Portion of compound colony, illustrating the way in which cone-in-cone structures arise in sections along s–t ( $\times 420$ ); E, Compound colony showing branching lines which represent margins of simple colonies ( $\times 100$ ).

with slightly flattened or rounded apices, directed towards the collapsed central cavity. In horizontal sections, they are usually seen at the margins of the colonies. Smaller cones may occur within larger ones, producing a cone-in-cone structure. This is seen in sections passing through the side of a colony, built up by the development of new cups within the mother-cell cups that have become extended but still retain their identity (Section t-s, Fig. 2D). Radiating and branching lines (Plate i, E), forming large structures, are usually present in both vertical and horizontal sections of compound colonies. These lines are heavier and more definite than the fine lines formed by sections through cell cups and thimbles, and represent the margins of the simple colonies in the compound colonies (Fig. 2E).

#### *Distinction between Spores and Algal Bodies.*

The general appearance of algal colonies may be compared with the macrospores shown in Plate i, F and G. It will be noted that the spores possess sharp-cut, well-defined margins; and the internal structures, when present, consist of typical markings, shown by distinct lines. The algal colonies possess indefinite "fuzzy" margins, frequently appearing pitted; and the internal structures consist of minute cell cavities, in compact masses regularly arranged in groups or radiating cones. Spores are preserved in clear, structureless substance, while the material of algal colonies is less transparent, being flecked with tiny inclusions of club-like bodies and opaque specks; and variations in refractive index give an uneven distribution of transmitted light. Characteristics, typical of macrospores and normal algal colonies, serve to distinguish between microspores and very small, algal colonies. Both spores and algal colonies are anisotropic in thin sections; but all the algal colonies, in any one section, are optically continuous, with respect to the polarization laminae (Dulhunty, 1939a), extending across the full width of the section.

#### *Coorongite and its Relations to Torbanite.*

The recent algal deposits of coorongite, forming from time to time in the vicinity of the Coorong, South Australia, have attracted much attention, owing to the peculiar nature of the substance, and the question of its origin.

It was originally believed to be the remains of some cryptogamic plants; but Thiselton Dyer (1872) showed that its composition resembles that of a hydrocarbon rather than a carbohydrate, and suggested that it might be the secretion of a plant, or the product of an oil spring. David (1889) recognized the similarity, with regard to certain properties, between coorongite and torbanite. Cumming (1903) also demonstrated the hydrocarbon nature of coorongite. Zalesky (1914) studied organic deposits closely resembling coorongite in the Ala-Kool of Lake Balkhash (see p. 27), and suggested genetic relations between this material and torbanite.

Coorongite was observed forming on the surface of shallow lakes near the Coorong in 1919 (Mawson, 1938), when it became evident that it was formed by microscopic pond-life. The true algal nature of coorongite was clearly demonstrated by Thiessen (1925), but he suggested that it was a type of alga previously unknown. The more recent work of Blackburn (1936) and Temperley (1936) has placed, beyond all doubt, the fact that the alga, responsible for the formation of coorongite, is *Botryococcus Braunii*. This is now generally accepted (Chapman, 1941).

Coorongite collected from the Coorong region, together with specimens supplied by Sir Douglas Mawson, have been examined by the author. It possesses an extraordinary degree of toughness and elasticity, giving the well-known rubber-like properties. Flat pieces, half an inch to an inch in thickness, can be folded in two without breaking, after which they will return to their original shape. It is sufficiently soft to be cut with a knife-blade, but firm enough to be scratched with a sharp point, which produces a light-yellowish streak. When broken or torn, the fracture surface is dark greenish-brown in colour and exhibits a bright, resinous lustre.

New coorongite is translucent to bright light in sections up to half an inch in thickness. Its substance is compact and homogeneous, with the exception of sand-grains and vascular-plant material, accidentally introduced. The specific gravity is slightly greater

than 1.0. It ignites readily in the flame of a match, and burns with a bright, smokeless flame, which is almost odourless.

The microscopic structures of coorongite have been described in detail by the investigators who have established its origin. Thin sections of coorongite can be prepared for microscopic examination by means of a microtome, or merely by cutting thin shavings with a razor and staining with alcoholic safranin. All sections show some trace of the algal structures already described in connection with the interpretation of the structures in torbanite. Some specimens exhibit well-preserved colonies, with typical grouping of thimbles (due to regular cell division) and stalk-like features, formed by the fusion of the basal portion of older cups. Other specimens show very little structure at all, owing to almost complete fusion of the algal debris to form an apparently structureless mass.

The principal evidence confirming the fact that coorongite represents the algal "peat-stage" of torbanite may be summarized as follows:

1. Both substances are composed of the remains of a unicellular colonial alga.
2. In the case of coorongite, the alga is the living form *Botryococcus Braunii*. In the case of torbanite, it is an alga so closely related to *Botryococcus Braunii* that botanical authorities consider the creation of a new genus unjustified.
3. Coorongite possesses toughness and elasticity unique among recent organic deposits; torbanite possesses elasticity and resilience unequalled by any other carbonaceous sediment.
4. Coorongite consists essentially of hydrocarbons, as compared with the carbohydrates of vascular-plant debris. Torbanite, when heated, produces paraffin oils, as would be expected from the thermal decomposition of polymerized, fatty hydrocarbons. Coal, derived from vascular-plant debris, produces an aromatic tar, when heated, as would be expected from the thermal decomposition of bituminized carbohydrates.
5. Both coorongite and torbanite are similar with respect to colour of streak, lustre, fracture, specific gravity, general colour, high volatile/fixed carbon ratio (proximate analysis), high hydrogen content (ultimate analysis), and oxidation products when heated with nitric acid.
6. If the oil yield from thermal decomposition is expressed as a percentage by weight of the volatile content, the figure for torbanite varies between 60 and 90%: coorongite between 65 and 75%; coals and cannel coals between 15 and 40%.
7. Both coorongite and torbanite emit a strong, light yellowish-white fluorescence in ultra-violet radiation, while ordinary peats, coals and cannel coals, derived from vascular-plant debris, do not fluoresce at all.
8. Sections of coorongite and torbanite transmit amounts of infra-red radiation much larger than ordinary coals, cannel and oil-shales.
9. Coorongite possesses unusual properties of resistance to decay and atmospheric oxidation, which would enable it to be preserved and fossilized under ordinary conditions of burial in coal-measures.

There seems to be no doubt that torbanite is derived from an algal sapropel which was the chemical, physical and biological equivalent of coorongite. That organic evolution should have allowed the organism to remain almost unchanged over the immense length of time which has elapsed since the Permian coal-measures were laid down is extraordinary, but similar stability of form appears to have existed during the descent of other primitive organisms, such as the brachiopod, *Lingula*; although, in some cases, new and more complex forms may have been derived by evolutionary branching from the stable lines of descent. The very primitive nature of the living *Botryococcus* suggests that the organism has not changed for a very long time, and justifies the belief that it has descended from the late Palaeozoic alga preserved in torbanite, without appreciable modification.

#### ENVIRONMENT OF DEPOSITION.

The environment of deposition may be regarded as a broad heading which covers the major geological problems relating to the origin of torbanite. It includes the study of conditions under which the organic matter accumulated, as well as those effecting its

preliminary preservation. The conditions of accumulation have been studied, firstly, with respect to the regional environments of sedimentation producing the coal-measures in which the torbanite deposits occur, and secondly, in relation to the conditions prevailing in the localities where the algal deposits were formed. Finally, consideration has been given to the environment of preservation enabling the algal remains to be preserved prior to, and immediately after, burial.

*Palaeogeographical Considerations.*

The occurrence and general distribution of torbanite in New South Wales have been described (Carne, 1903; Dulhunty, 1942*a*). Deposits occur in both the Upper and Lower (or Greta) Coal Measures of the Kamilaroi System. These two divisions of coal-measures represent distinct phases of sedimentation, being separated by thick beds of marine strata. In considering the palaeogeographical relations between coal-measure sedimentation and the formation of torbanite, the Upper Coal Measures will be dealt with first, as they are the most important torbanite-bearing strata, and provide more evidence relevant to the problems of origin.

The area originally occupied by Upper Coal Measure sediments is indicated in Fig. 3, which has been reproduced from a previous paper (Dulhunty, 1942*a*). The measures were deposited in what may be described as the original "Kamilaroi Basin"; but the use of this term, in referring to the whole area in which coal-measures occur, is somewhat confusing and perhaps unwise, as later earth movements warped the Kamilaroi sediments into three separate, structural areas: the coastal area from Newcastle in the north to Nowra in the south, extending westward to Lithgow, Rylstone

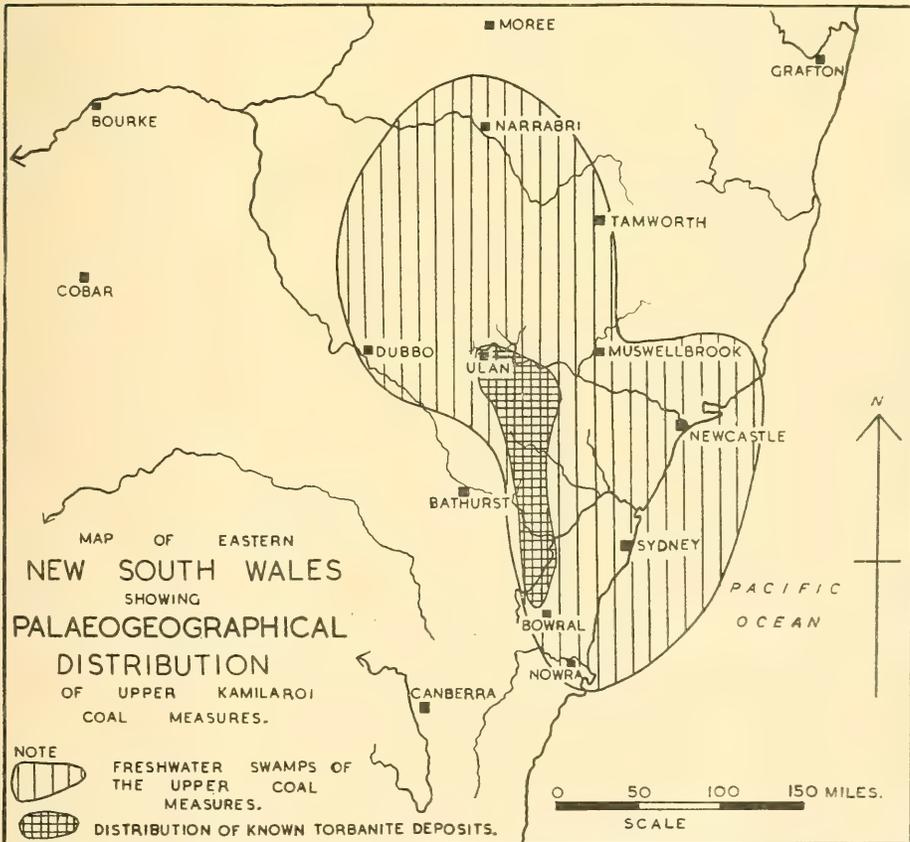


Fig. 3.—Map showing the relation between the distribution of known torbanite deposits and the probable area covered by the freshwater swamps of the Upper Coal Measures.

and Muswellbrook (Raggatt, 1938); the Oxley Basin (Dulhunty, 1940), situated between Muswellbrook, Coolah and Gunnedah; and the south-eastern margin of the Great Artesian Basin between Gunnedah, Dubbo and Narrabri (Kenny, 1928, 1929; Lloyd, 1935; Dulhunty, 1939*b*). It is intended, for the purpose of the present paper, to refer to the coastal area, extending inland to Lithgow and Rylstone, as the *South-Eastern Region* of the Kamilaroi deposition, and those portions now within the Oxley and Great Artesian Basins between Muswellbrook, Dubbo and Narrabri, as the *North-Western Region*.

The most important deposition of coal-measures took place in the South-Eastern Region, which included the original centre of Kamilaroi deposition. The central portion of this region is covered by Triassic sediments; but outcrops occur in the southern, south-western, western and northern sides, in areas known as the Southern, South Western, Western and Northern Coalfields, respectively. Outcrops, occurring on the southern side of the Oxley Basin along the Goulburn River between Ulan, Rylstone and Baerami (Dulhunty, 1941), will be considered a part of the Western Coalfield in the following discussion.

*Distribution of Torbanite in the Upper Coal Measures.*—Although the Upper Coal Measures extend over the wide region indicated above, the formation of torbanite was confined to a comparatively small, elongated area, trending roughly north-west and south-east along the western side of the South-Eastern Region, within the Western and South-Western Coalfields as illustrated in Fig. 3. Detailed evidence of this distribution has been discussed by the writer (Dulhunty, 1942*a*).

The Upper Coal Measures are comparatively thin (less than 600 feet) along the western and south-western margins of the South-Eastern Region; but they attain great thicknesses amounting to over 3,000 feet in the central portions, where there are upper and lower sections known as the Newcastle and Tomago Stages, respectively. In the Western and South-Western Coalfields, where torbanite deposits occur, the upper or Newcastle Stage alone is represented, having overlapped the Tomago Stage (Dulhunty, 1941; Raggatt, 1938). No deposits have been found in the Tomago Stage, although it outcrops extensively in the Hunter Valley. It follows that the torbanite-formation in the Upper Coal Measures was confined not only to the western side of the South-Eastern Region, but also to the Newcastle Stage. The stratigraphical distribution of deposits within the Newcastle Stage has been described and illustrated (Dulhunty, 1942*a*), showing that the majority of the deposits occur in the lower portions, while in the top-most portion, above the No. 2 Coal Seam, there is none. A definite tendency persists for torbanite to occur on, or near, coal-bearing horizons.

The grouping of the torbanite deposits on the western side of the South-Eastern Region, their confinement to the Newcastle Stage of the Upper Coal Measures, and their limitation to certain zones within this stage, call for an explanation which must be sought in terms of regional environment and changing conditions of sedimentation.

*Regional Conditions of Upper Coal Measure Deposition.*—The palaeogeography of the Upper Coal Measures has been dealt with by several writers, including Walkom (1913), David (1932) and Raggatt (1938). The main events, important in relation to the origin of torbanite, may be summarized as follows:

The coal-measures of the Tomago Stage were built up by sediments derived from lands of low relief, under conditions of general quiescence. The change from these conditions to those which produced the sediments of the Newcastle Stage was accompanied by important earth movements. There was extensive elevation of country surrounding the basin, and high lands resulted, particularly to the north-east. A great land mass, described by Sussmilch and David (1919) and David (1932) as *Tasmantis*, existed to the east of the present coastline, forming an effective barrier to the sea. Continued sinking of the basin, particularly in the northern and central portions, gave rise to widespread deposition of freshwater sediments (the Newcastle Stage), which covered the entire area previously occupied by the Upper Marine sea. Coal-forming conditions of the Newcastle Stage occurred during brief periods of calm, alternating with rapid deposition, due to rejuvenation of the drainage and flooding of the basin. Conditions gradually became less vigorous as the land surfaces were reduced almost to base-level.

At the close of Permian time, there appears to have been renewed elevation of surrounding lands, which produced the Narrabeen Beds of the Triassic.

The author, having studied certain palaeogeographical problems in connection with the distribution and origin of torbanite deposits, suggests the following conclusions:

The Upper Marine and Upper Coal Measure sediments, occurring in the North-Western Region, accumulated in a north-western extension of the main area of deposition in the South-Eastern Region. As far as can be ascertained, the Upper Coal Measures in the North-Western Region represent the Newcastle Stage; and it seems highly probable that the coal-forming swamps of the Tomago Stage did not extend to the north-west for any appreciable distance beyond the limits of the present Hunter Valley. The Permian sediments of the North-Western Region were warped by later earth-movements, so as to be included in the Oxley Basin and the south-eastern margin of the Great Artesian Basin. Mesozoic sediments were deposited in these basins, covering the Permian strata with thick beds of Triassic and Jurassic rocks. Owing to the lack of recent uplift and dissection, the Permian beds, to a large extent, still remain buried.

The Upper Marine beds in the North-Western Region consist of coarse sandstone, conglomerates, tillites and boulder beds. They are continuous, through the Gulgong-Ulan-Rylstone districts, with the Upper Marine outcropping along the western side of the South-Eastern Region; but marine fossils are generally absent. Possibly, some of these deposits may represent freshwater, fluvio-glacial sediments, contemporaneous with the true marine beds of the South-Eastern Region. The absence of Tomago coal-measures, along the western side of the South-Eastern Region and also in the North-Western Region, means that a considerable time-break must have occurred in these areas, between the close of Upper Marine deposition and the development of Newcastle coal-measures. During this interval, the area of sedimentation moved to the east, where Tomago coal-measures accumulated. It follows that certain areas, where Newcastle measures lie directly on the Upper Marine, must have remained more or less stable during the time-break, as depression or elevation would have resulted in deposition of Tomago beds, or wide-spread removal of Upper Marine strata, respectively. Evidently, considerable quantities of sediments were transported across these areas, to be deposited further to the east as the Tomago beds. This suggests that recession of the sea, at the close of Upper Marine time, left the marginal Upper Marine sediments stranded slightly above or at the base-level of sedimentation; and that the rivers, which had supplied their sediments, passed over the marine beds by cutting shallow channels and delivered sediments to the area in which Tomago measures were deposited.

Coal-forming conditions, within the North-Western Region, appear to have resulted from the fact that a slight depression brought the stranded Upper Marine beds once again within the area of sedimentation; and Newcastle coal-measures were deposited. The measures so formed were relatively thin, and appear to have been deposited in shallow, swampy areas. Outcrops, available along the eastern and south-western margins of the North-Western Region, indicate that the coal-measures are continuous, although variable in thickness. Conglomerates and coarse sandstones are generally absent from the measures of the North-Western Region, with the exception of the eastern shore-line deposits between Murrurundi and Gunnedah, where coarse sediments are common. This suggests that country of low relief prevailed to the north, west and south-west, with high land to the east.

In view of the foregoing palaeogeographical considerations, it is possible to draw the following conclusions, of importance concerning the distribution of torbanite deposits:

1. Conditions of general quiescence prevailed throughout the deposition of the Tomago coal-measures, the sediments being supplied by sluggish rivers from country of low relief.

2. During the deposition of the Newcastle coal-measures in the South-Eastern Region, sediments were supplied by active mountain streams, subjected to periodic rejuvenation and flooding. This would give rise to large supplies of freshwater round the margins of the basin, while more sluggish conditions would exist in the central portions.

3. Deposition of Newcastle coal-measures in the North-Western Region was accomplished under moderate conditions involving slow transport of sediments, similar to the accumulation of the earlier Tomago measures. Only slight sinking of the area occurred. There is no evidence of the periodic rejuvenation and flooding which took place in the South-Eastern Region.

4. The marginal sediments, produced under vigorous conditions along the western side of the South-Eastern Region, are unique: similar sediments, formed along the eastern side, having been submerged by the Pacific Ocean, and those of the northern side having been removed by erosion.

*Correlation between Distribution of Torbanite Deposits and Regional Conditions of Upper Coal Measure Deposition.*—The vigorous marginal conditions of sedimentation, which produced the coal-measures along the western side of the South-Eastern Region, may be correlated with the confinement of torbanite deposits to the western margin of the Newcastle measures. Conversely, the absence of deposits in the North-Western Region can be correlated with the conditions of general quiescence, under which the measures were laid down. Similarly, the more sluggish conditions, which must have existed during the deposition of the central portions of the Newcastle coal-measures in the South-Eastern Region, appear to have resulted in the absence of torbanite. The same feature applies to the Tomago coal-measures, which were deposited under conditions of quiescence, and do not contain torbanite deposits. Furthermore, the occurrence of only one deposit above the No. 3, or Dirty Coal Seam, and the complete absence of deposits above the No. 2 Coal Seam, within the torbanite-bearing area of the Newcastle Stage, can be correlated with the fact that conditions of sedimentation became less vigorous towards the close of Upper Coal Measure deposition.

The correlation of vigorous marginal conditions of coal-measure deposition and rapid transport of sediments, with the formation of torbanite deposits, requires an explanation to show how these conditions could control the development of torbanite. Such an explanation may be found in the influence of decaying vegetation on the growth of the alga, and the facilities provided for the development of algal sapropel by the specialized marginal environment of sedimentation.

A characteristic feature of torbanite is the absence of vascular-plant remains, in particular the dark brown jelly or ulmo-humic, colloidal derivative produced by the decay of vascular plants. This substance gives a brown colour to water, in which plant material is decaying, and permeates the fibrous plant debris of peat, where it forms a stiff jelly when sufficiently concentrated: it is the dark brown groundmass of most coals and cannels, and constitutes the principal substance of structureless vitrain. Only in rare cases (material transitional between torbanite and coal) has any of this humic product been found in association with the algal sapropel of torbanite.

It is evident that conditions, favouring accumulation of humic product and development of the alga, are mutually exclusive, or else the humic product prevents the growth of the alga. Both factors are probably involved, but the latter would seem to be the most important for the following reasons:

1. High concentrations of the humic product would prevent aeration of the water, and deprive the alga of oxygen and carbon dioxide.

2. The humic product contains humic acids, which react with the minerals dissolved in the water and precipitate insoluble humates. This would deprive the alga of its supplies of dissolved mineral matter, which is essential to its growth.

3. The precipitation of humates may form a flocculent coating on the algal colonies, preventing their normal development and respiration.

4. The brown coloration of the water, due to the presence of humic product, would reduce the amount of sunlight available to the alga.

5. The humic product may be toxic to the alga, in a manner similar to the toxic effect it is believed to have on bacterial decay of vascular-plant material.

The relations between the conditions of coal-measure sedimentation, quantity of humic product in the water, and the development of the alga, must be taken into account, at this juncture, to explain the correlation of torbanite-formation with vigorous marginal conditions of sedimentation. Details of the local environment, required for

the formation of algal peat, are treated fully later in the paper. It is sufficient, for the present discussion, to infer that the deposits were formed in small, isolated lakes, filled by the penetration of backwaters through peat beds or marshes from flowing water-courses some distance away.

The presence of lenticular deposits of torbanite, cannel coal, clay shales and other accessory materials on the main coal-bearing horizons in the Upper Coal Measures indicates shallow-water conditions, with the surface of sedimentation only partially covered by water, rather than the deposition of the coal-forming debris in large, completely submerged areas. Large rivers, bringing water and sediments to the regions of sedimentation, must have passed across the marginal areas in wide, meandering watercourses of ever changing form, with banks of peat and sub-aerial swamp-vegetation. Towards the central portions of the basin, these watercourses dispersed by means of distributaries, and eventually became lost in swampy areas and peat bogs. Isolated lakes would be formed in marginal areas by the washing out of peat bogs, and meanders being cut off during periods of flood. Similar lakes were formed, less frequently, in the central areas by unequal deposition of sediments from floods, and lowering of the general water-level during normal periods. Such lakes, both marginal and central, received supplies of water by percolation through peat beds and marshes from the main channels of moving water. In marginal areas, the water, penetrating to the isolated lakes, would be comparatively fresh from the mountain streams, and would carry dissolved gases and mineral matter, but would not have been in contact with the decaying vegetation of peat bogs long enough to become heavily charged with humic product. This provided the necessary physical as well as chemical environment for the formation of algal sapropel.

The isolated lakes in the central areas would receive supplies of stagnant water, poorly aerated and containing a high concentration of humic product, gathered during its passage through, perhaps, fifty miles of decaying vegetation. These conditions, accompanying sluggish deposition, are most unlikely to have supported an abundant growth of the alga, for reasons already given; and it is considered that, in Upper Coal Measure time, they were the principal factors determining the absence of torbanite deposits in the whole of the North-Western Region, the whole of the Tomago Stage, the central portion of the Newcastle Stage in the South-Eastern Region, and the top of the marginal facies of the Newcastle Stage in the Western and South-Western Coalfields.

It is suggested, therefore, that the formation of torbanite was confined to the margin of the Newcastle coal-measures along the western side of the South-Eastern Region, owing to the development of isolated lakes filled with backwaters, containing a low concentration of humic degradation products, having soaked through peat beds and swamps from channels carrying fresh, aerated water of mountain streams.

*Distribution of Torbanite and Conditions of Sedimentation in the Lower or Greta Coal Measures.*—The Lower or Greta Coal Measures of the Northern Coalfield were deposited in an elongated trough, crossing the present coast-line in the vicinity of Newcastle and passing inland to the north-west, probably, to Gunnedah. The measures are relatively thin, but contain one important coal-bearing horizon, on which the Greta Coal Seam is situated. Torbanite occurs as thin, irregular bands, in the Greta Coal Seam, at various points along the outcrop of the measures, from Murrurundi in the north-west through Muswellbrook to Greta, Maitland and Cessnock in the south-east.

The Greta measures extend considerably beyond the limits of Lower Marine deposition, particularly to the north-west, indicating the development of low lands to the north-west of the area occupied by the Lower Marine sea. Probably most of the Greta measures were laid down under conditions of general quiescence; but marginal conglomerates, described by Raggatt (1938), occur along the north-eastern shore-line, and pass into sandstone towards the centre of the basin. These marginal facies suggest that high lands existed to the north-east, and that conditions of vigorous deposition occurred along the north-eastern shore-line. The outcrops of the Greta Coal Seam, containing torbanite, are situated along the north-eastern side of the area of deposition, suggesting a correlation between torbanite-formation and specialized marginal sedimentation, similar to the correlation already described in the case of the Upper Coal Measures.

The central portion and south-western margin of the Greta Coal Measures do not outcrop; and it is not known whether the occurrence of torbanite is confined to the north-eastern margin, or not. Thus evidence regarding distribution of torbanite in the Greta measures is incomplete; but its occurrence in the outcrops along the north-eastern margin is compatible with the hypothesis requiring special marginal conditions for torbanite-formation.

Greta Coal Measures, containing torbanite, were also deposited in small lakes in the Clyde River district. The coal-forming environment, which existed in this small lake-area, no doubt involved conditions approximating to marginal sedimentation, as large central areas of sluggish deposition and stagnant water would not have been present.

It may be concluded that evidence from the Greta Coal Measures supports the conclusions with regard to palaeogeographical control of torbanite-formation in the Upper Coal Measures; but the evidence is incomplete and can not be regarded as conclusive.

*Evidence from the Formation of Recent Algal Sapropel.*

The geological history and structure of the Coorong region, South Australia, has been described briefly by Mawson (1938). The Coorong is a narrow strip of salt water, ninety miles long. It communicates with the ocean at the mouth of the Murray River, from which it runs in an easterly direction, parallel to the coast, while a coastal dune separates it from the open sea. The adjacent, low-lying country on the northern side of the Coorong is known as the Coorong region. It consists of late Tertiary to Recent sediments, lying almost horizontally on an old basement of Pre-Cambrian and early Palaeozoic rocks. The basement was reduced to a peneplain by early Tertiary time, and was tilted to the south by Miocene movement which brought it below sea-level, and resulted in the deposition of Miocene and early Pliocene marine sediments, before it emerged in middle Pliocene time (Mawson, 1938).

The country, reclaimed from the sea by slight late-Tertiary elevation, is now the low area in which coorongite forms. The area is only slightly above sea-level, and its drainage is partially held up by calcareous sand-dunes. This results in the formation of swamps, lakes and pools, varying from fresh-water to saturated brine. Many of the swamps and small lakes are filled during seasons of excessive rainfall, but at other times are dry. Some of these are filled by direct run-off during wet seasons, and others by back-waters from channels communicating with the Coorong. Several of the permanent lakes are inhabited by different kinds of microscopic algae and other organisms, giving green, blue and purple colours to the waters. In the spring of 1939, the writer observed several lakes with a greenish hue, due to the presence of *Botryococcus Braunii*, while others possessed bluish-green and reddish colours. It appears that *Botryococcus* is present every year in some of the lakes, but only occasionally in sufficient abundance to form deposits of coorongite.

The conditions required for maximum development of the alga seem to have existed in temporary lakes, filled by the flooding of main drainage channels in the area. A dry lake, in which coorongite had previously formed, was examined in some detail. It consisted of a small basin-like feature, with a depth of about fifteen feet, and an average width of about sixteen chains, as illustrated by the section in Fig. 4. The surrounding country was covered with dense scrub, terminating abruptly at the margins of the lake, the shore-line of which, for the greater part, was well defined by a comparatively steep profile. The lake-floor consisted of Tertiary limestone, covered with sandy soil a few inches to several feet in thickness (Fig. 4). One section of the shore-line was very low, with scrub growing practically at the level of the lake-floor, and from this point, low scrub-covered land extended to a neighbouring lake connected by means of a swampy channel to a nearby creek. Evidently flood-waters from the creek had "backed up" into the first lake, and then found their way through low, scrub-covered land to the second lake, where coorongite had formed as a result of phenomenal algal growth.

Lakes, carrying large stocks of *Botryococcus* in 1939, were isolated from the main water channels by dunes or swampy areas with sub-aerial vegetation. The formation of

coorongite in 1919 was described as occurring in "shallow ponded flood-waters" (Mawson, 1938). The existing lakes, carrying stocks of *Botryococcus*, contain but little sub-aerial swamp-vegetation of a vascular nature, and the dry beds of those in which coorongite had formed are free from terrestrial plants. Filling of the lakes has occurred sufficiently to prevent the establishment of terrestrial plants, and, when filled, the water is usually too deep to allow the growth of sub-aerial plants.

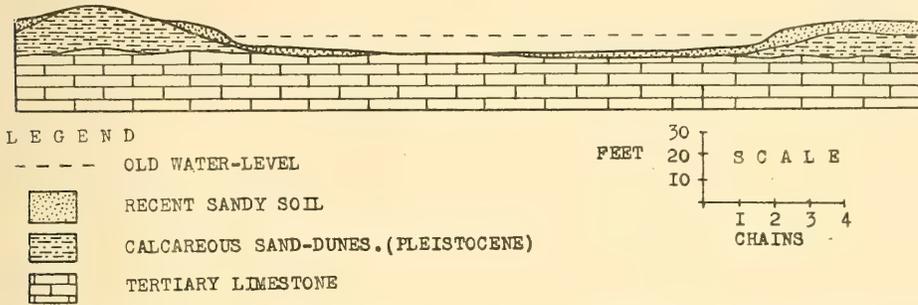


Fig. 4.—Generalized geological section across a "coorongite lake" in the Coorong region, South Australia.

Conditions, favouring maximum growth of the alga and subsequent formation of coorongite, would appear to exist when comparatively fresh flood-waters, having deposited most of their sediment, migrate through swamps and scrub-covered dunes into a dry depression, free from permanent terrestrial flora and possessing no definite outlet, through which the impounded waters can escape. The newly-formed pond would be free from currents which, under other circumstances, would remove the alga as it developed; the water would be well aerated, and contain sufficient humic degradation product to supply available nitrogen for the alga, but insufficient to interfere with its growth. Fine suspended sediment, remaining in the water after its infiltration to the pond, would slowly settle during the early stages of algal development, leaving only dissolved mineral matter to be assimilated by the alga. Low, dense scrub, surrounding the pond, would allow a maximum amount of sunlight to enter the water, and also shield it from excessive wind, which may cause disturbing wave action. Such conditions, following the cold, wet winter of the Coorong region, could be expected to promote vigorous growth of *Botryococcus*, which is an alga of temperate climates.

The first evidence of excessive development of the alga is the formation of a scum on the surface of the water. This was described by Blackburn (1936) in a laboratory culture, and by Mawson (1938) in connection with the 1919 development of coorongite in South Australia. The scum appears to be formed by dead algal colonies which have risen to the surface owing to the development of gas bubbles from the decaying cells. After complete decomposition of the cells, the decay-resisting substance of the cell cups and thimbles coalesces to form the tough, rubbery mass of coorongite, which remains on the bed and sides of the depression after the water has receded.

The lake areas of Gippsland and south-western Victoria are said to be somewhat similar, geographically, to the Coorong region; but evidently the particular set of conditions, favouring the development of *Botryococcus* in the Coorong lakes, does not occur there, as excessive algal growth and the occurrence of coorongite, as far as can be ascertained, have not been reported.

#### *Formation and Preservation of Permian Algal Sapropel.*

*Accumulation.*—The local conditions, favouring the accumulation of algal sapropel in Permian time, can be deduced from evidence obtained in the study of the formation of recent algal sapropel or coorongite, and the palaeogeographical data concerning the distribution of torbanite in the Kamilaroi coal-measures. This evidence, detailed under previous headings, suggests the following environmental factors:

1. High country existed along the north-eastern side of the trough, in which the Greta Coal Measures were deposited, and the western margin of Upper Coal Measure deposition in the area of the Western and South-Western Coalfields.

2. The high lands provided rivers carrying large quantities of water and sediment.

3. The sudden change, in gradient and transporting power of the rivers at the shore-lines of coal-measure deposition, resulted in unequal distribution of sediments in marginal areas.

4. Excess sediments, dropped by the rivers, produced an uneven surface of sedimentation at, or slightly above, water-level in marginal areas.

5. On reaching the shore-lines, the rivers became large, meandering watercourses, passing towards the central regions of sedimentation, where the mean water-level was probably higher than the surface of the sediments.

6. Frequent flooding of the rivers and marginal areas occurred.

7. Isolated lakes of temporary nature were formed in marginal areas by uneven deposition of excess sediments, the washing out of peat bogs and silt beds, and the development of "cut-off" meanders belonging to the main watercourses.

8. The isolated lakes received supplies of water from the main channels by infiltration through swamps, peat beds, sand dunes, and silt beds.

9. Fluctuations in the water-level, due to variations in the volume of water delivered by the mountain rivers, caused alternate filling and emptying of the lakes, preventing the permanent establishment of either swamp or terrestrial vegetation.

10. The water, penetrating to the lakes, was well aerated, and carried fine, suspended sediment, dissolved mineral matter, and only small quantities of humic products of decaying vegetation.

11. The lakes, when filled, were suitable for the abundant development of the Permian ancestor of *Botryococcus Braunii*.

Some torbanite deposits possess floors of coal, indicating that the original algal lake had existed in a depression or washout in a peat bed. The torbanite is frequently separated from its coal floor by a thin, clay band, which means that fine sediment, brought in with the water, had time to settle before algal development commenced. Many deposits have floors of clay shale, while others lie upon sandstone. In these cases the algal lakes must have existed on beds of silt or sand formed by earlier floods.

The recent formation of coorongite, by surface accumulation of decomposing alga, produces masses of sapropel, in which the colonies are fused together without intervening, inorganic matrix. Similar sapropel existed as the original debris of some torbanites, in which there is no continuous skelëton of inorganic matrix. In such cases, the algal debris probably accumulated at the surface, until decomposition of the cells was complete, came to rest at the bottom of the lake—either by virtue of its density, or by the recession of the water—and was eventually buried. Most torbanites, however, possess larger amounts of inorganic matrix embedding the colonies, which suggests that the algae accumulated on the bottom of the lake to form a bed of sapropel containing evenly distributed sediment. This would be expected to occur if small amounts of fine sediment were introduced during the periods of algal development. These sediments would sink the colonies and entomb them on the lake-floor. Such introduction of sediment was probably effected by continuous infiltration of water at one side of the lake, and its slow escape through another, or the floor, without causing sufficient current to upset the settling of fine sediment. Vertical variation in the amount of inorganic matrix is common. This could be caused by repeated flooding of the main watercourses, giving fluctuation in the amount of introduced sediment, or possibly, by variations in climatic conditions influencing the rate of algal development.

The torbanite deposits consist of either one layer of torbanite, or several well-defined layers, from a few inches to several feet in thickness, separated by bands of cannel coal, or clay shale. The author believes that each layer of torbanite was built up by no more than one annual period of algal growth. The following are the reasons supporting this belief:

Periodic seasonal growth is certain to have occurred, as all microscopic algae possess well-marked maximum and minimum phases of annual development (Chapman, 1941).

All separate periods of growth must be marked by some banded feature. The deposition of sediment, which occurred during algal growth, must have continued, to a greater or smaller extent, in the absence of the alga, giving rise to a clay shale band—if no plant debris were introduced. Any vascular-plant material—either indigenous, drifted or wind-borne—introduced during the absence of the alga, would mingle with the inorganic sediment to form cannel coal. If the water receded from the lake, during the season in which the alga ceased to grow, some wind-blown debris or surface-oxidation effect would be certain to produce a band or break in vertical continuity. Some feature, however small, would have been formed, as all the natural factors of sedimentation would tend to produce a line of demarcation between the seasonal periods of algal growth. Quite possibly, a sudden change in some factor may have produced a banded feature in the sapropel from one season's growth, in which case the layers of torbanite would be equivalent to less than one year's accumulation. Thus, it appears evident that each uniform layer of torbanite must represent part or whole of one season's growth, and can not be the accumulation of several seasons.

Homogeneous layers of torbanite two feet in thickness, without any break in vertical continuity, are known to occur in some deposits. This introduces the question of compression, and the original thickness of algal sapropel required to give such layers, which, in view of the foregoing, were probably built up during one season. The living algal colonies were globular or more or less spherical; but the fossil colonies in torbanite are flat, disc-shaped bodies, for which the ratio of width to thickness averages about 6 to 1. The ratio for dead algal colonies, in coorongite which has not been compressed at all, is about 2 to 1, due to collapse after death. The increase in the ratio from 2 to 1, to 6 to 1, is evidently due to compression after burial under superimposed sediments. Most torbanites contain very little inorganic matrix separating the fossil colonies, and the increase in the ratio of width to thickness of the discs, after burial, appears to be a true measure of the extent to which the original layers of algal sapropel were reduced in thickness by compression. The average increase in the ratio from 2 to 1, to 6 to 1, means that the layers were reduced to three-eighths of their original thickness, or that a layer of torbanite, 1 foot in thickness, represents an original layer of algal sapropel 2 feet 8 inches in depth, or that the thick, homogeneous layer of torbanite, amounting to 2 feet, would indicate a bed of sapropel originally 5 feet 3 inches deep. These compression ratios are lower than those calculated for coal (Raistrick and Marshall, 1939), as would be expected, owing to the greater compressibility of a spongy, fibrous, coal-forming peat, compared with the compact mass of algal sapropel.

The eukerogenic and dyskerogenic forms of algal sapropel, previously described (Dulhunty, 1943*a*), appear to have originated during accumulation. A possible explanation of the differentiation into the two forms is to be found in the following facts: The fatty substance of the cups, in algal colonies, represents excess food supplies secreted by the cells (Chapman, 1941). Variations in the relative amounts of material, derived from fatty cups and cuticular thimbles, have been noted in living colonies (Blackburn, 1936). Such variations probably depend on environment: favourable conditions cause secretion of large quantities of fatty substances which, on distillation, give higher oil yields than the material of the thimbles. Thus, it is possible that optimum conditions of growth give rise to eukerogenic sapropel, while an unfavourable environment produces the dyskerogenic form. The greater depth of colour, possessed by the latter, is probably due to the secretion of excess pigment, under unfavourable conditions of growth; and other properties (colour of streak, colour of fracture surface, optical density, ratios of volatile/fixed carbon, oil/organic matter and oil/gas), characteristic of the two forms after transformation to torbanite, are undoubtedly related to the intrinsic nature of the substances constituting the cups and thimbles.

*Preservation.*—One of the outstanding properties of algal sapropel, formed from the remains of *Botryococcus Braunii*, is its remarkable resistance to weathering and decay. Masses of coorongite, collected from dry lake-beds in the Coorong region, have withstood desiccation and the effects of wet conditions for periods of from ten to twenty years. The only changes wrought by such exposure are increases in hardness, toughness, and depth of colour. The elasticity, bright lustre, lightness of streak, and hydro-

carbon affinities remain. The substance of the sapropel is particularly immune from oxidation as well as bacterial attack. Micro-sections, cut across the surface of coorongite exposed to atmospheric weathering for about twenty years, show an opaque, brittle, oxidized surface of no more than one millimetre in thickness. Other masses of coorongite, partially buried in moist soil, have not yielded to bacterial decay. These properties are probably due to the fact that the living algal cell secretes about itself a fatty cup and cuticular thimble designed to give protection from desiccation and bacterial attack for several years, while in the resting stage awaiting favourable conditions for growth.

Preservation of ordinary coal-forming peat depends on the prevention of natural oxidation and bacterial decay. Oxidation and the action of aerobic bacteria must be prevented by a covering of stagnant water, silt or organic debris. The action of anaerobic bacteria must be controlled by the formation of toxic products. The preservation of algal sapropel is relatively simple, compared with that of coal-forming peat, as natural resistance to decay and oxidation allow it to await burial for long periods of time, without special conditions of preservation. The rarity of occurrence of torbanite in the coal-measures of the world can not be due to difficulties in preservation, but rather to the very special conditions required for abundant algal growth.

*Burial.*—The predominance of inorganic sediments in the New South Wales coal-measures, even on the coal-bearing horizons in marginal areas, indicates frequent and widespread deposition of silt and sand over the area of sedimentation. Under such conditions, the probability of the burial of algal sapropel, within a period of from twenty to thirty years after formation, would be great. A minor change in the course of a main channel near the algal lake, or the spreading of silt and sand beds by an unusually large flood from adjoining high lands, would effect the burial of the algal sapropel, and give the clay shale or sandstone strata which commonly form the roofs of torbanite deposits.

Burial under organic debris also occurred, giving coverings of coal and cannel. This resulted, no doubt, from the establishment of vascular swamp-vegetation, caused by the lakes becoming shallower, or the entry of a flowing stream carrying vascular-plant debris.

Once covered, the algal beds would remain indefinitely, to be slowly changed by metamorphic processes into the torbanite deposits of today.

#### METAMORPHIC EVOLUTION OF THE TORBANITE DEPOSITS.

The simple subsidence and elevation, to which the coal-measures of the Western and South-Western Coalfields have been subjected, would be unlikely to have had any special metamorphic effect on the torbanite deposits. The warping, which occurred in the Greta measures of the Northern Coalfield, and the strong faulting along their north-eastern margin appear to have had little effect on the torbanite—apart from the development of occasional slickenside faces and local shear-zones. The principal factors, causing metamorphic evolution of torbanite, were pressure from overlying strata, geological time and moderate earth temperatures.

#### *Conditions of Metamorphism.*

An attempt has been made to estimate the approximate conditions of pressure and temperature to which the torbanite deposits have been subjected during consolidation. Owing to the complex nature of such problems, the estimates are necessarily very approximate, but they have been made with the object of indicating the order of magnitude of the factors involved.

*Pressure.*—In the estimations of rock pressures in connection with the study of isostasy, it is usual to assume that differential pressure is equivalent to about 25 per cent. of the total hydrostatic pressure, owing to the rigidity of the rocks and the necessity of overcoming the resistance equal to the forces required to cause shearing movement. On this basis, the differential pressure exerted by a column of rock in a downward vertical direction would be no more than 25 per cent. of the weight of the column, owing to the reaction with the adjoining columns, which are supported by the basement. It would appear, however, that this principle would not apply to the present

problem, as the torbanite deposits are interbedded with coal and other sediments extending over a large area, and constituting a stratum which would yield to vertical compression as much as, if not more than, the deposits of torbanite. This means that the overlying strata would not be supported by rocks surrounding the deposits, and the columns of rock, above each deposit, would not be held up by reaction with the adjoining columns.

The overlying strata would be supported by basement rocks only at the margins of the basin of deposition, and the area of this basin was very large, while the thickness of the overlying rocks was relatively small. Thus, the influence of the marginal support, depending on the rigidity of overlying rocks, would be negligible. It follows that the weight of overlying rocks would act as a vertical compressional force, which, within any small area of the torbanite-bearing stratum, would be equal to the total weight of the column of rock immediately above the area concerned. Each deposit may be considered a small area within the compressible stratum, and the compressional force, to which the torbanite has been subjected, may be calculated from the total weight of rock overlying the deposit.

In the case of deposits occurring in the Upper Coal Measures of the Western and South-Western Coalfields, the maximum depth of cover, existing before uplift and erosion, varied considerably, increasing with the distance from the old shore-line. It is probable that some of the deposits nearest the shore-line, such as that of Tong Bong Mountain, were covered by no more than 100 feet of coal-measures and 500 feet of Triassic sandstone. Others, further from the shore-line, including Baerami and Glen Davis, appear to have been buried beneath 150 to 300 feet of coal-measures, and as much as 2,000 feet of sandstone. In estimating maximum pressures to which the deposits may have been subjected, the overlying strata must be considered to have been saturated with water, at the time when subsidence of the area of deposition ceased. The average weight per cubic foot of sandstone is about 160 lb., and for shale about 170 lb. A reasonable figure for the porosity of the Triassic sandstone would be about 7 per cent., and for coal-measure shales, about 1 per cent. Therefore, the weight per cubic foot of saturated sandstone could be taken as 164 lb., and for shale 171 lb.

Assuming an average cover of 100 feet of shale and 500 feet of sandstone, for deposits nearest the old shore-line, the maximum weight per cubic foot on the torbanite would have been in the vicinity of 99,000 lb., representing compressional force or pressure of approximately 690 lb. per sq. in. Deposits furthest from the shore-line, with an average cover of 200 feet of shales and 2,000 feet of sandstone, were probably subjected to a pressure of the nature of 2,500 lb. per sq. in. Thus, it appears that the maximum pressures endured by the torbanite deposits of the Western Coalfield varied from about 700 to 2,500 lb. per sq. in.

In the Greta Coal Measures of the Northern Coalfield, the maximum depth of cover is very difficult to estimate, owing to contemporaneous warping and erosion, and the complete removal of Triassic beds from the greater part of the area in which the Greta measures outcrop. In the Hunter Valley area, Upper Marine beds vary from 3,000 to 4,000 feet; Upper Coal Measures from 2,000 to 3,000 feet; and the Triassic, now removed, probably amounted to, at least, 1,500 feet. It seems reasonable to assume a maximum cover of, perhaps, 7,500 feet, composed of sandstone, conglomerate, shales and tuffaceous rocks. These strata were probably equivalent to about 3,000 feet of shale and 4,500 feet of sandstone, representing a pressure of 8,700 lb. per sq. in. The cover was much less towards the north-west, and, probably, the pressure on the torbanite, in the vicinity of Murrurundi, did not exceed the pressures estimated for the Upper Coal Measures in the Western and South-Western Coalfields.

It is evident that the pressures have been relatively moderate. The probable maximum of 8,000 to 9,000 lb. per sq. in. can not be considered very great, compared with pressures of 30,000 to 40,000 lb. per sq. in. used in modern hydraulic presses for moulding and consolidating materials. Pressures as high as 280,000 lb. per sq. in. have been used in experimental work on the consolidation of peat (Stevenson, 1916).

*Temperature.*—The maximum temperature to which the deposits have been subjected is a matter of considerable speculation, although it can be shown, with a reasonable

degree of certainty, that the average temperatures have been very moderate. The progressive sinking of the area of Kamilaroi deposition, from Carboniferous to Triassic time, probably resulted in a depression of the geo-isotherms; but the still-stand in the latter part of Mesozoic time, and the elevation of the Tertiary period no doubt allowed them to rise.

Temperature gradients have been determined in deep bores and shafts put down through the Triassic sandstone into the Upper Coal Measures in the Sydney district (David and Pittman, 1893, 1894; Rae, Pittman and David, 1899). The results of these determinations show that the rate of increase of rock temperature downwards, at Cremorne and Balmain, averages about 1°F. for every 85 feet, commencing with a mean surface temperature of 63°F. The Sydney district is situated in an area which was only slightly uplifted by Tertiary elevation. The upper portion or Wianamatta Stage of the Triassic is little above the present sea-level at many places, and the Kamilaroi beds, now 3,000 feet below sea-level, can not be far removed from their original position, when subsidence and deposition ceased at the close of Triassic time. Assuming that the geo-isotherms have risen slightly during the latter part of Mesozoic time and the Tertiary Era, it is reasonable to take the present sub-surface rock temperature in the Sydney district as the average maximum temperature to which the Kamilaroi strata have been subjected. On this basis, it is probable that the torbanite deposits of the Greta Coal Measures have not been heated above 150°F., while those of the Upper Coal Measures have probably not exceeded 100°F.

Certain portions of some torbanite deposits may have been heated to temperatures much higher than those estimated above, owing to their proximity to igneous intrusions, but such heating has been very local; and in no case can it be considered to have influenced the metamorphism of the whole of any one deposit. The average, maximum temperature of 150°F. is very moderate, and such heating, at atmospheric pressure, has no apparent effect on either coorongite or torbanite. Apparently, rock temperatures have not played an important part in the transformation of coorongite to torbanite.

*Time.*—As the torbanite deposits are of Permian age, the time factor is very great, and appears to have been the most important feature in the metamorphism of algal remains, providing opportunity for chemical and physical changes to occur at a rate which would be considered negligible under laboratory conditions.

#### *Physical and Chemical Changes.*

The main physical changes, accompanying the formation of torbanite from the original algal deposits, involve increase in hardness, reduction in elasticity, production of a compact and homogeneous texture, slight increase in depth of colour, and development of a tendency to split in a direction parallel to the bedding plane. Properties, remaining more or less unchanged, include specific gravity, colour of streak, lustre, and conchoidal fracture in directions oblique to the bedding. Certain optical changes occur, such as increase in refractive index of the algal material, increase in optical density, and development of anisotropism including "polarization laminae".

Chemical changes taking place during the transformation of the algal remains are of considerable importance. The ultimate and proximate compositions of coorongite and torbanite, of about the same ash content, are indicated in Table 1. A marked decrease occurs in oxygen content, and a slight reduction in the amount of hydrogen, with a corresponding increase in carbon content. Proximate analyses show reduction in hygroscopic moisture and considerable increase in the volatile/fixed carbon ratio.

TABLE I.  
*Ultimate and Proximate Compositions Typical of Coorongite and Torbanite.*

Material.	Ultimate Composition.				Proximate Composition.			
	C.	H.	O.	N.	H <sub>2</sub> O.	Vol. Cont.	F. Carb.	Ash.
Coorongite .. ..	78.4	12.0	8.9	0.7	1.7	80.3	7.0	11.0
Torbanite .. ..	85.0	10.0	4.3	0.7	0.5	75.0	13.0	11.5

Changes in ultimate and proximate compositions indicate a process of slow carbonization, somewhat similar to, but far less marked than, coalification of peat, which involves elimination of much greater quantities of oxygen.

Organic matter of coorongite consists of natural oils, fatty materials and small quantities of carbohydrates, much of the material being soluble in organic solvents. After transformation to torbanite, the organic matter is completely insoluble in common organic solvents at their boiling-points under atmospheric pressure. Recent experimental work, carried out by the writer (Dulhunty, 1942*b*, 1942*c*, 1943*b*), has shown that the organic matter can be rendered soluble by heating at temperatures between 280° and 340°C., which are lower than those causing thermal decomposition, and that the change to the soluble form does not involve evolution of volatiles or gas-formation. Soluble products, thus formed, are very heavy hydrocarbons, which can be converted to paraffins and olefines by thermal cracking.

The conversion of the organic matter to the soluble form by heating appears to be a kind of depolymerization, and it is accompanied by the development of a soft, "rubbery" condition, closely resembling the pliable nature of organic matter in coorongite. The soluble product of heated torbanite contains less oxygen than the substance of coorongite, owing to elimination of this element during natural carbonization. Apart from deficiency in oxygen, which enhances its hydrocarbon properties, the product is similar, in its empirical chemical composition, to the original algal remains in coorongite. These facts suggest that the change from coorongite to torbanite involves a polymerization process, which slowly reduces solubility and increases hardness of the organic matter, and that the effect of heating torbanite is to reverse the process, causing depolymerization, which increases solubility and reduces hardness.

Oxidation of coorongite and torbanite with hot nitric acid gives oxidation products of the nature of fatty acids, which appear to be generally similar, although detailed chemical work has not been carried out along these lines.

Evidently, the most important chemical changes involved in the transformation of coorongite to torbanite have been of the nature of molecular rearrangements and structural modifications, rather than fundamental changes in chemical composition.

Certain inorganic chemical changes have also occurred during the formation of torbanite. Chalcedonic silica frequently occurs within the gelosite and retinosite bodies. Its occurrence has been studied by the writer (Dulhunty, 1939*a*), and it has been shown that silica has replaced the organic matter, giving rise, in some cases, to siliceous torbanites of no commercial value. The fact that siliceous replacements take the form of the flattened, disc-shaped bodies means that invasion by siliceous waters occurred after preliminary burial and slight compression; but it is highly probable that it was early in the metamorphic history, while the organic matter was still soft and small cavities remained, as replacement would be unlikely after the hard, compact gelosite and retinosite had been formed. Variations in hardness of the inorganic matrix, in torbanites containing appreciable amounts of silt, indicate different degrees in cementation, resulting from inorganic reactions similar to those which accompany the consolidation of clay shales.

#### *Metamorphic History.*

As already stated, a thin covering of sediment was sufficient to prevent atmospheric oxidation and bacterial decay. With continued subsidence, the deposits of algal sapropel were rapidly covered by greater thicknesses of sediment, protecting them from contemporaneous erosion which would be likely to occur at the surface. Soon after burial, the organic matter probably commenced to undergo a process of slow polymerization, the molecules of oil and fatty substances forming large, condensed ring-structures.

During the earlier stages of transformation, circulating ground-waters, charged with dissolved mineral matter, permeated the deposits, causing cementation of the inorganic matrix and effecting replacement of varying quantities of organic matter by silica. As greater thicknesses of strata accumulated above the deposits, pressure gradually increased, helping to consolidate the algal remains into a compact mass, and driving out excess water. With continued polymerization, the organic matter became less soluble.

and, probably, more resistant to attack from inorganic solutions. It also became harder and commenced to lose its elasticity, although an extraordinary degree of toughness remained. In addition to molecular rearrangement, the process of natural carbonization commenced to eliminate oxygen and small amounts of hydrogen from the condensing molecules, but less rapidly than in the case of coal-formation, due to early polymerization and stability of the algal substance. This, possibly, contributed to the high oil-producing properties of torbanite.

Continued sinking of areas of deposition built up great thicknesses of overlying strata, and pressure on the deposits commenced to reach the maximum, amounting from 5,000 to 9,000 lb. per sq. in. in some cases; but the algal matter must have been hard and very tough at this stage, as there is no evidence of torbanite having been forced into fissures, veins or sills. Earth temperatures, amounting to, perhaps, 150°F. in the Greta Coal Measures, were insufficient to play any important part in metamorphism, and would not even affect the moisture content, under existing pressures. It is probable that the relatively low temperatures allowed polymerization to proceed without excessive carbonization.

Having reached the stage of hard, compact material under pressure, the deposits attained an extremely stable condition; and further polymerization and carbonization must have proceeded at a very slow rate. Probably the deposits in the Greta measures reached this stage by the end of Permian time, and Upper Coal Measure deposits during the latter part of the Mesozoic Era. The slow rate of change, in advanced stages of metamorphism, is evident from the fact that torbanites of the Greta and Upper Coal Measures are almost identical in their degree of evolutionary development. Those of the Greta measures are slightly harder, but other physical and chemical properties are similar. The slight difference in hardness may be due to advanced metamorphism, but it could also be caused by the greater pressures attained in the Greta measures. It is, however, a very small degree of difference, when we consider that the Greta torbanites antedate those of the Upper Coal Measures by a length of time equivalent to half of the Permian period.

During the latter part of the Mesozoic Era and early Tertiary time, the deposits probably remained almost unchanged, and elevation and erosion of Triassic and Kamilaroi sediments, during Tertiary and Pleistocene time, have brought to the surface, once again, the ancient algal deposits which are now hard, compact and chemically-stable torbanite.

#### BRIEF SUMMARY OF MAJOR EVENTS IN THE ORIGIN OF TORBANITE.

The regional environment was that of low-lying marginal areas of Permian coal-measure deposition, receiving large quantities of water and sediment from mountain streams, subjected to frequent rejuvenation and flooding. Local conditions, promoting algal development, were obtained in isolated lakes formed by washing out of silt and peat beds, and by meanders being cut off from main channels which carried water and sediment across the marginal areas of deposition. Water entered the lakes by percolating from flowing streams through peat bogs, marshes, and sand beds. This water carried dissolved and suspended mineral matter with small quantities of humic degradation products. Variations in water-level, in the main channels, alternately filled and emptied the lakes, preventing the establishment of either terrestrial or sub-aerial plant-vegetation. When the lakes were filled in spring or summer, the Permian ancestor of *Botryococcus Braunii*, under suitable climatic conditions, flourished and took possession of the water. After the algal cells had died and decayed, the fatty and cuticular skeletons of algal colonies sank from the surface, or were carried down with sediments to form layers of sapropel on the lake-beds. In some lakes, seasonal growth of algae, during successive years, built up several layers of sapropel, separated by bands of clay or canneloid peat. These bands were due to the settling of sediment, or introduction of vascular-plant sapropel, in the absence of the alga. The deposits were finally covered with silt or peat beds to become part of the coal-measure strata. After burial, polymerization of the algal substance and the weight of overlying beds, changed the deposits to relatively hard, compact material, although, in some cases, siliceous waters attacked the organic

matter and partially replaced it with chalcedony. Metamorphism continued during the immense length of time the deposits remained buried, under pressures up to 9,000 lb. per sq. in. and temperatures of 100° to 150°F. The algal remains were subjected to natural carbonization, but its effect was limited, owing to stability brought about by early polymerization. Subsidence of the area of deposition ceased at the close of Triassic time, and transformation to torbanite was completed during the latter part of the Mesozoic Era. Tertiary elevation brought the coal-measures to the surface, resulting in dissection and the exposure of torbanite in existing outcrops.

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## EXPLANATION OF PLATE I.

- A.—Vertical section of torbanite showing the collapsed central cavities of algal colonies. Baerami deposit. (× 125.)  
 B.—Horizontal section of torbanite, illustrating the botryoidal appearance typical of compound colonies. Hartley Vale deposit. (× 150.)  
 C.—Vertical section of torbanite showing oval-shaped structures representing oblique sections of thimbles. Wollar deposit. (× 1,000.)  
 D.—Horizontal section of torbanite showing funnel-shaped structures representing the basal portions of old thimbles. Hartley Vale deposit. (× 750.)  
 E.—Vertical section of torbanite showing compound colonies with branching lines formed by the margins of simple colonies. Morts Upper Seam, Katoomba. (× 250.)  
 F.—Spore in horizontal section of coal. (× 50.)  
 G.—Spores in vertical section of coal. (× 45.)

## REVISION OF AUSTRALIAN LEPIDOPTERA. OECOPHORIDAE. XI.

By A. JEFFERIS TURNER, M.D., F.R.E.S.

[Read 29th March, 1944.]

Owing to war conditions this instalment of the revision has been delayed more than twelve months. Before commencing the revision of the large genus *Philobota*, it is necessary to record some corrections and omissions in previous instalments, and a number of new species of allied genera.

I take this opportunity of referring to the serious loss we have sustained by the recent deaths of Mr. G. M. Goldfinch and Mr. W. B. Barnard. Mr. Goldfinch undertook the revision of the difficult family Boarmiadae, of which no completely satisfactory classification has appeared as yet. He has left in manuscript much important structural work on this family; and it is a great misfortune that he did not live to complete his revision. Mr. Barnard was an untiring and most successful collector of all groups of Lepidoptera, and to him we owe a large number of new species from all regions of Australia.

Two of the generic names proposed in Part x have been preoccupied. I propose therefore for *Actenista* the name *Heterolecta* (ἑτερολεκτος, later chosen), and for *Lophoceros* the name *Ecnomolophos* (ἐκνομολοφος, with unusual antennae).

To those species of which I have seen no example † is affixed.

365. BAREA PISSINA Turn. is a *Eulechria* and may be placed before *E. zophoptera* Turn. (843).

829. EULECHRIA MYRIOSPILO Low. *Philobota lissopolia*, Proc. Roy. Soc. Tasm., 1926, p. 152, is an additional synonym of this species.

1003. PACHYBELA EREMICA Turn. *P. parisa* Turn. (1004) is a synonym.

1117. The genus *Oxybeles* is withdrawn, as Meyrick has shown that the character on which it is based, the separation of 3 and 4 of the hindwings, is inconstant. The species *gnomica* Meyr. should be referred to *Machaeritis* and placed before *M. polemistis* Meyr. (1109).

1167. OCYSTOLA CALLISTICHA Turn. Mr. N. B. Tindale observed this species taking short flights from damp moss on tree-trunks in bright sunshine on the Macpherson Range.

1203. OLBONOMA POLIOPHRACTA Turn. must be transferred to *Ocystola* following *O. suppressella* Wlk. (1161).

1245. COESYRA AMYLODES Meyr. should be transferred to *Ocystola* and follow *O. mesoxantha* Meyr. (1178).

1311. COESYRA ACTINODES Turn. must be referred to *Hippomacha* and follow *H. pyrochrysa* Meyr. (1188).

1325. OCYSTOLA LEUCOSTEMMA Turn. This and *O. delographa* Turn. (1327), *O. clethrosema* Turn. (1320) and *O. cyphomochla* Turn. (1328) should follow *O. poliophracta* Turn. (1203).

1329. OCYSTOLA ACATHARTA Turn. should come after *O. proselia* Turn. (1172).

1332. OCYSTOLA PYRGOPHORA Turn. This, *O. auchmera* Turn. (1333) and *O. nigricincta* Meyr. (1334) should follow *O. mesoxantha* Meyr. (1178).

1488. TANYZANCLA CHIONOSTOLA Turn. *T. pentatypa* Turn. (1493) is a synonym.

1542. TANYZANCLA CINETICA should be removed from that genus to *Philobota* and follow *P. melichrodes*.

The following species (1548-1557) have been omitted from previous papers:

1548. EULECHRIA ORTHOGRAMMA Meyr., Proc. Linn. Soc. N.S.W., 1884, p. 725. This should follow *E. malacoptera* Meyr. (537). (N.S.W.: Sydney. S. Aust.: Mt. Lofty; Pt. Victor.)

1548A. COESYRA AETHALEA Meyr., Proc. Linn. Soc. N.S.W., 1883, p. 380. I place this next *C. apora* (1342) though with some doubt. (Mt. Gambier; Mt. Lofty.)

1549. EULECHRIA LIMATA Meyr., *Exot. Micro.*, i, p. 168. This should follow *E. griseola* Zel. (818). (W. Aust.: Waroona.)

1550. EULECHRIA GONIOTICHA Turn., *Proc. Roy. Soc. Tasm.*, 1938, p. 90. This should follow *E. hypnotis* Meyr. (852). (Tasm.: Weldborough.)

1551. EULECHRIA ALBIFRONS Turn., *Proc. Roy. Soc. Tasm.*, 1938, p. 90. This should follow *E. tephrochroa* Turn. (871). (Tasm.: Waratah.)

1552. EULECHRIA IRENITIS Turn., *Proc. Roy. Soc. Tasm.*, 1938, p. 91. This should follow the preceding species. (Tasm.: Cradle Mt., 3,000 ft.)

1553. EULECHRIA SPRETA Turn., *Proc. Roy. Soc. Tasm.*, 1938, p. 91. This should follow *E. stigmatophora* Turn. (889). (Tasm.: St. Marys.)

1554. COESYRA GYPSOMERA Low., *Trans. Roy. Soc. S. Aust.*, 1920, p. 62. This should precede *C. byssodes* Turn. (1222). (Tasm.: Hobart.)

1555. COESYRA CHRYSOIDES Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 67. This should follow *C. miltozona* Low. (1269). (N.S.W.: Sydney. Qd.: Stradbroke I.)

1556.† COESYRA CROCINASTIS Meyr., Proc. Linn. Soc. N.S.W., 1888, p. 1656. This and the next should precede *C. distincta* Turn. (1292). (W. Aust.: Carnarvon.)

1557. COESYRA COMOXANTHA Meyr., Proc. Linn. Soc. N.S.W., 1888, p. 1657. (W. Aust.: Geraldton.)

1558. CORETHROPALPA RHODODACTYLA, n. sp. (ῥοδοδακτυλος, rosy-fingered.)

♀. 22–25 mm. Head whitish sometimes brownish-tinged. Palpi with second joint long, porrect, clothed with rough hairs above and beneath, except near base, those on lower edge longer and forming a strong apical tuft, terminal joint ascending, slender, acute; second joint towards apex fuscous edged beneath by rosy, internal surface and terminal joint white. Antennae grey. Thorax whitish edged anteriorly by rosy and laterally by fuscous. Abdomen grey. Legs grey; posterior pair whitish. Forewings rather strongly arched, apex acute, termen very obliquely rounded; grey-whitish; a clear white costal streak edged with fuscous from base to beyond middle; a broad fuscous median streak from one-third to two-thirds, there forked, upper branch to just before and lower to slightly beneath apex; a fuscous line edged with rosy from disc at one-third to tornus; some rosy and fuscous irroration above dorsum; cilia grey, from beneath apex to tornus with white bases. Hindwings and cilia pale grey. Except for some resemblance to *Eclecta aurorella* Meyr. the pattern and coloration of the forewings are unique. It should precede *C. melanoneura* Meyr. (948).

Queensland: Stanthorpe in December (W. B. Barnard); two specimens.

1559. SAROPLA ATAUROTA, n. sp. (ἀταυρωτος, virginal.)

♀. 16 mm. Head and thorax white. Palpi with second joint exceeding base of antennae, terminal joint one-third; white. Antennae grey, basal joint white. Abdomen grey. Legs grey; posterior pair white. Forewings narrow, costa gently arched, apex pointed, termen very oblique; white very sparsely sprinkled with grey; cilia grey-whitish, extreme apices fuscous, on tornus wholly white. Hindwings and cilia grey. I place this and the next species after *S. amydropis* Meyr. (964).

Victoria: Mt. Buffalo in January; one specimen.

1560. SAROPLA GLAGOESSA, n. sp. (γλαγοεις, milky.)

♀. 24 mm. Head and thorax white. Palpi with second joint more than twice length of face, anterior edge of second joint beyond middle clothed with long rough hairs forming a strong apical tuft; white. Antennae pale grey. Abdomen grey, apices of segments white. Legs grey (posterior pair missing). Forewings with costa moderately arched, apex obtusely pointed, termen obliquely rounded; white, lightly sprinkled, and veins slenderly outlined, with pale grey; cilia white. Hindwings and cilia white.

Queensland: Injune in October (W. B. Barnard); two specimens. Type in Queensland Museum.

#### 85. Gen. ANTIOPALA Meyr.

To my definition of this genus should be added: Hindwings elongate-ovate.

133. Gen. ASPASIODES, n.g. (*ἀσπασιοδης*, well pleasing.)

Characters as in *Antiopala*, but hindwings lanceolate. Type: *A. epicompsa* Turn. I refer here also *A. gennaea* Turn. and *A. xanthospila* Turn.

1561. ASPASIODES EPICOMPSA, n. sp. (*ἐπικομψος*, decorated.)

♀. 12-13 mm. Head and thorax yellow. Palpi with terminal joint three-fifths; pale yellowish. Forewings slightly dilated, costa gently arched, apex rounded, termen obliquely rounded; dark fuscous; markings yellow; a triangular fascia from a point just before midcosta, extending on dorsum from one-fifth to middle; a straight narrow line from beneath two-thirds costa to tornus; a transversely elongate subapical spot; cilia dark fuscous. Hindwings dark fuscous; a broad transverse yellow band before middle; cilia dark fuscous. I place this before *A. gennaea* Turn.

North Queensland: Kuranda in September; two specimens received from Mr. F. P. Dodd.

1562. ASPASIODES ALLOPHYLIA, n. sp. (*ἀλλοφυλος*, different.)

♂. 14 mm. Head grey-whitish. Palpi with terminal joint one-half; white, terminal joint fuscous. Antennae fuscous; ciliations in male two-thirds. Thorax whitish-grey faintly purple-tinged. Abdomen fuscous. Legs fuscous with whitish rings; posterior pair mostly fuscous. Forewings narrow, costa rather strongly arched, apex rounded, termen strongly oblique; whitish-grey faintly purple-tinged, with some fuscous sprinkling in terminal half; markings blackish; a short slender interrupted streak from base of costa; a broader longitudinal streak from base of dorsum, narrowing to a point at one-fourth; an oblong costal spot from one-fourth to three-fourths, reaching beyond middle of disc, containing a central spot of ground-colour; cilia grey sprinkled with fuscous. Hindwings and cilia grey. A neat and striking species, which may follow *A. xanthospila* Turn.

Queensland: Injune in August (W. B. Barnard); one specimen.

1563. ANTIOPALA MODERATA, n. sp. (*moderatus*, unassuming.)

♂. 17 mm. Head shining white. Palpi with second joint reaching base of antennae, terminal joint one-half; smooth, slender; white, base of second joint fuscous. Antennae fuscous; ciliations in male 1. Thorax dark fuscous with white anterior and posterior spots, the latter larger. Abdomen whitish-grey; tuft whitish-ochreous. Legs ochreous-whitish; anterior tibiae and tarsi fuscous. Forewings narrow, costa nearly straight, apex pointed, termen very oblique; white; markings light fuscous ochreous-tinged; a costal line from base to one-third; two parallel oblique lines at one-third and two-thirds; some irroration in disc; an irregular terminal suffusion; cilia white, on apex and tornus fuscous. Hindwings and cilia whitish. Place this after *A. anomodes* Meyr. (1018).

Queensland: Stanthorpe in January; one specimen received from Mr. W. B. Barnard.

1564. ANTIOPALA FURTIVA, n. sp. (*furtivus*, concealed.)

♂. 14-16 mm. Head whitish. Palpi with terminal joint two-thirds; whitish. Antennae fuscous; ciliations in male 1. Thorax fuscous. Abdomen grey. Legs fuscous; posterior pair grey. Forewings with costa strongly arched, apex rounded, termen obliquely rounded; whitish; markings fuscous, more or less suffused; a basal suffusion, sometimes confined to costa; an indistinct suffused fascia at one-fourth; a more distinct median fascia, broadest on costa, narrowing in disc, usually not reaching dorsum; a terminal fascia sometimes confluent with it; a terminal whitish patch more or less developed; sometimes a terminal line; stigmata dark fuscous, but often not developed, first discal at one-third, plical beneath it, second discal at two-thirds; cilia whitish more or less suffused with fuscous. Hindwings and cilia grey. To be placed before *A. tephraea* Meyr. (1019).

New South Wales: Ebor in December; six specimens.

1565. ANTIOPALA ALBESCENS, n. sp. (*albescens*, whitish.)

♂. 25 mm. Head ochreous-whitish. Palpi very long, second joint more than three times length of face, terminal joint one-half; ochreous-whitish. Antennae ochreous-whitish, towards apex grey; ciliations in male 1. Thorax ochreous-grey-whitish. Abdomen and legs grey; tuft ochreous-grey-whitish. Forewings with costa moderately arched, apex pointed, termen sinuate; ochreous grey-whitish; stigmata minute, blackish,

first discal at one-third, second before two-thirds; cilia whitish. Hindwings grey-whitish; cilia whitish. Larger than others of the genus, and palpi much longer. It may be placed last.

Victoria: Frankston, near Melbourne, in November; one specimen.

1566. *MICROLOCHA TETRAMOCHLA*, n. sp. (τετραμοχλος, four-barred.)

♂. 11 mm. Head blackish; face shining white. Palpi smooth, slender; terminal joint one-half; shining white, terminal joint fuscous. Antennae fuscous; ciliations in male slightly over 1. Thorax blackish, posterior edge white. Abdomen fuscous. Legs whitish; anterior pair fuscous. Forewings narrow, costa rather strongly arched, apex pointed, termen very obliquely rounded; white with well-defined fuscous markings; a large spot on base of dorsum reaching half across disc; a moderate oblique fascia from one-third costa to mid-dorsum; a second fascia from two-thirds costa to three-fourths dorsum; a subterminal fascia not reaching margins; a terminal series of dots; cilia pale grey, bases rosy-tinged. Hindwings and cilia grey.

Queensland: Mt. Tamborine in October; one specimen.

1567. *MACHAERITIS LECHRIOMOCHLA*, n. sp. (λεχριομοχλος, obliquely barred.)

♂. 13-14 mm. Head white. Palpi short, reaching middle of face, terminal joint one-fourth; white. Antennae grey; ciliations in male 2. Thorax with anterior half white, posterior half fuscous. Abdomen grey. Legs grey; anterior pair fuscous. Forewings narrow, costa slightly arched, apex pointed, termen very oblique; white with fuscous markings; a narrow basal fascia; rather narrow oblique fasciae, first at two-fifths, second from three-fourths costa to tornus; a terminal line; cilia fuscous, interrupted above and below middle by white bars. Hindwings and cilia grey. To follow *M. encrita* Low. (1068), which besides other differences has much narrower hindwings.

Queensland: Toowoomba in November; two specimens. Type in Queensland Museum.

1568. *MACHAERITIS OXYPTILA*, n. sp. (όξυπτίλος, sharp-winged.)

♂. 15 mm. Head white. Palpi with terminal joint one-half; white, second joint except apex fuscous. Antennae grey with some white annulations; ciliations in male 2. Thorax white sprinkled with fuscous. (Abdomen missing.) Legs fuscous with whitish tarsal rings. Forewings narrow-lanceolate, costa gently arched, apex acute, termen extremely oblique; white; markings fuscous; a basal costal spot; four costal dots between two-fifths and apex, the second dot largest; from beneath second dot a narrow fascia to termen just above tornus; a series of dots close to termen; cilia white with a series of median dots in costal half. Hindwings and cilia grey. To follow *M. naias* Meyr. (1074a).

Queensland: Injune in May (W. B. Barnard); two specimens. Type in Queensland Museum.

1569. *MACHAERITIS PLEUROMOCHLA*, n. sp. (πλευρομοχλος, with costal bar.)

♂. 13-14 mm. Head and thorax whitish. Palpi with terminal joint one-half; fuscous. Antennae fuscous; ciliations in male 1. Abdomen grey. Legs grey; anterior pair fuscous. Forewings narrow, costa gently arched, apex pointed, termen very oblique; whitish very lightly sprinkled with fuscous; markings fuscous; a broad costal line from base to one-fourth or one-third; stigmata minute, not always all developed, first discal at one-third, plical beyond it, second discal at two-thirds, sometimes a dot above and between discals; a tornal spot or suffusion; cilia whitish. Hindwings pale grey; cilia whitish. To follow *M. samphoras* Meyr. (1078).

Queensland: Springbrook (Macpherson Rge.) in October (W. B. Barnard); two specimens. Type in Queensland Museum.

1570. *MACHAERITIS GYPSOPLACA*, n. sp. (γυψοπλακος, white-blotched.)

♂. 14 mm. Head white. Palpi with second joint fuscous, at apex white (terminal joint missing). Antennae fuscous; in male serrulate, ciliations 4. Thorax dark fuscous; patagia white. (Abdomen missing.) Legs fuscous. Forewings with costa gently arched, apex round-pointed, termen straight, oblique; a triangular dark fuscous basal fascia extending on costa to one-eighth; a fuscous line from one-fourth costa to one-third dorsum; the space between this and basal fascia clear white; a narrow dark fuscous fascia, its median portion grey-brown, from costa near apex to tornus; median area between last two markings grey-brown; a dark fuscous dot below middle at two-thirds; a terminal dark fuscous-brown fascia not reaching tornus; cilia grey-whitish, on apex

and costa dark fuscous. Hindwings pale grey; cilia whitish. The type of this very distinct species, despite the imperfections noted, is in good condition. I place it after *M. platycapna* Turn. (1097).

Queensland: Tweed Hds. (Burleigh) in September (W. B. Barnard); one specimen.

1571. *MACHAERITIS OCHROCAPNA*, n. sp. (*ὄχροκαπνος*, pale and smoky.)

♀. 15–16 mm. Head whitish-ochreous. Palpi with terminal joint one-half; whitish, second joint, except apex, fuscous. Antennae fuscous. Thorax whitish-ochreous; patagia fuscous. Abdomen fuscous. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa slightly arched, apex pointed, termen very obliquely rounded; whitish-ochreous; a fuscous discal dot at two-thirds, slenderly connected with another above tornus; cilia whitish-ochreous. Hindwings dark grey; cilia grey. To come before *O. pavid*a Turn. (1100).

Queensland: Stanthorpe in February; two specimens.

1100. *Machaeritis pavid*a Turn. was based on a confusion of two species. I now describe them separately.

1572. *MACHAERITIS PAVIDA* Turn.

♀. 12 mm. Head ochreous-whitish. Palpi with terminal joint three-fifths; whitish, outer surface of second joint fuscous towards base. Antennae whitish with fuscous annulations; thorax and abdomen fuscous. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa moderately arched, apex pointed, termen very obliquely rounded; ochreous-whitish; markings suffused, fuscous; a spot on base of costa; a moderate fascia from two-thirds costa to mid-dorsum; a tornal dot; a suffused spot on costa before apex; cilia ochreous-whitish, on tornal dot fuscous. Hindwings and cilia pale grey.

Queensland: Macpherson Rge. (3,500 ft.) in March; one specimen.

1573. *MACHAERITIS THYSANOESSA*, n. sp. (*θυσανοεις*, fringed.)

♂, ♀. 10–12 mm. Head ochreous-grey; face glossy whitish. Palpi with terminal joint three-fifths; grey, inner surface whitish. Antennae whitish with fuscous annulations; ciliations in male 3. Thorax fuscous. Abdomen grey. Legs grey; posterior pair whitish. Forewings with costa gently arched, apex acute, termen very oblique; ochreous-whitish; a narrow basal fuscous fascia; some fuscous sprinkling towards apex and termen; cilia pale ochreous sprinkled with fuscous. Hindwings and cilia pale grey. This and the next three species should come before *M. grammophora* Meyr. (1101).

North Queensland: Malanda (Atherton Tableland) in August; four specimens.

1574. *MACHAERITIS ASEMANTICA*, n. sp. (*ἀσημαντικός*, insignificant.)

♂. 14 mm. Head and thorax ochreous-whitish. Palpi with terminal joint one-half; ochreous-whitish, outer surface of second joint except apex fuscous. Antennae fuscous; ciliations in male minute. Abdomen grey. Legs fuscous; posterior pair whitish. Forewings narrow, costa slightly arched, apex pointed, termen straight, oblique; whitish-ochreous; dorsal edge before middle and a tornal dot fuscous; cilia whitish-ochreous. Hindwings and cilia pale grey.

Queensland: Gladstone in June; one specimen.

1575. *MACHAERITIS MYRODES*, n. sp. (*μυρωδης*, oily.)

♂. 13–14 mm. Head and thorax whitish. Palpi with terminal joint one-half; whitish. Antennae grey; ciliations in male 1. Abdomen and legs grey. Forewings narrow, costa moderately arched, apex pointed, termen extremely oblique; glossy whitish; towards apex slightly sprinkled with fuscous; cilia whitish. Hindwings with cilia grey-whitish.

Queensland: Ebor in December; one specimen.

1576. *MACHAERITIS NEPHELOSPILA*, n. sp. (*νεφελοςπιλος*, with cloudy spots.)

♂. 16 mm. Head and thorax grey. Palpi with terminal joint three-fifths; grey. Antennae fuscous; ciliations in male one-half. Abdomen fuscous; tuft grey. Legs fuscous; posterior pair grey with white rings. Forewings narrowly elongate, slightly dilated, costa slightly arched, apex pointed, termen extremely oblique; grey finely sprinkled with grey-whitish; stigmata rather large, suffused, fuscous, first discal at one-third, plical beneath and partly fused with it, second at two-thirds, a spot beyond and in a line with plical; cilia grey. Hindwings and cilia pale grey.

Queensland: Maryland, near Stanthorpe, in February (W. B. Barnard); one specimen.  
1577. *MACHAERITIS CEDEA*, n. sp. (*κηδεος*, lovely.)

♂. 17 mm. Head white. Palpi with terminal joint one-fourth; white. Antennae pale grey, near base white; ciliations in male 2. Thorax white, with an anterior ochreous-brown spot. Abdomen grey; dorsum of first segment white; tuft grey-whitish. Legs fuscous-brown. Forewings narrow, costa straight almost to apex, apex acute, termen straight, oblique; clear white; markings golden-ochreous; a straight narrow fascia at two-fifths; a fascia from four-fifths costa to four-fifths dorsum, much swollen in disc to enclose a large circular spot, which almost fills it, and connected in middle with first fascia; a terminal line from apex to mid-termen; cilia golden-ochreous, on apex and tornus dark fuscous. Hindwings pale grey; cilia whitish. To follow *M. insolita* Turn. (1106).

Queensland: Carnarvon Rge. in December (W. B. Barnard); one specimen.

1578. *OCYSTOLA SPATHULATA*, n. sp. (*spathulatus*, spoon-shaped.)

♂. 16 mm. Head and thorax grey-whitish. Palpi with terminal joint one-half; whitish. Antennae pale grey; ciliations in male 1. (Abdomen missing.) Legs grey; posterior pair whitish. Forewings narrow at base, strongly dilated posteriorly (spathulate), costa slightly arched, apex rounded, termen very obliquely rounded; white, cilia white. Hindwings and cilia grey-whitish. Best recognized by the shape of the forewings. This and the next species should follow *O. vinoleuca* Turn. (1130).

West Australia: Waroona in October; two specimens.

1579. *OCYSTOLA MICROSTIGMATA*, n. sp. (*μικροστιγματος*, with minute stigmata.)

♂, ♀. 13-16 mm. Head and thorax grey-whitish. Palpi with terminal joint two-thirds; grey-whitish. Antennae grey-whitish; ciliations in male extremely long (8). Abdomen grey. Legs grey-whitish; anterior pair grey. Forewings narrow, costa slightly arched, apex rounded, termen very obliquely rounded; grey-whitish; stigmata minute, dark fuscous, first discal at one-third, plical beyond it, second discal before two-thirds; cilia concolorous. Hindwings and cilia grey-whitish.

New South Wales: Katoomba in February; Mt. Tomah, near Mt. Wilson, in March; two specimens.

1580. *OCYSTOLA LEPTOBAPHES*, n. sp. (*λεπτοβαφης*, faintly tinged.)

♂. 14-15 m. Head and thorax white faintly ochreous-tinged. Palpi with terminal joint one-half; white. Antennae pale grey; ciliations in male 2. Abdomen grey. Legs grey; posterior pair white. Forewings narrow, costa rather strongly arched, apex pointed, termen very oblique; white faintly ochreous-tinged; cilia white. Hindwings and cilia grey. To follow *O. hololeuca* Meyr. (1131).

Queensland: Stradbroke I. in October; one specimen.

1581. *OCYSTOLA DIPLOSTICTA*, n. sp. (*διπλοστικτος*, two-spotted.)

♀. 12 mm. Head and thorax white. Palpi with terminal joint one-half; white, external surface of second joint except apex grey. Antennae white. (Abdomen missing.) Legs whitish. Forewings narrow, costa moderately arched, apex pointed, termen strongly oblique; white with slight fuscous irroration towards termen; minute fuscous dots at one-half and two-thirds; cilia white. Hindwings and cilia whitish. To follow *O. abductella* Wlk. (1132).

Queensland: Gladstone in September; one specimen.

1582. *OCYSTOLA LINOPIIS*, n. sp. (*λινωπις*, like linen.)

♀. 15 mm. Head and thorax whitish tinged ochreous-grey. Palpi with terminal joint two-thirds; grey-whitish. Antennae and abdomen grey. Legs grey-whitish; anterior pair grey. Forewings sub-oblong, costa moderately arched, apex rounded, termen obliquely rounded; whitish tinged with ochreous-grey; stigmata minute, grey, scarcely perceptible, first discal at one-third, second at two-thirds; cilia concolorous. Hindwings pale grey; cilia grey-whitish. To follow *O. micropasta* Turn. (1133).

1583. *OCYSTOLA TRICHO CEROS*, n. sp. (*τριχοκερως*, with hairy horns [antennae].)

♂. 20 mm. Head pale grey. Palpi with terminal joint three-fourths; pale grey. Antennae pale grey; ciliations in male extremely long (8). Abdomen pale grey. Legs whitish; anterior pair fuscous. Forewings with costa slightly arched, apex acute, termen sinuate, oblique; pale grey; stigmata minute, fuscous, first discal before one-third, second

before two-thirds; cilia pale grey. Hindwings and cilia whitish. To follow *O. nivea* Meyr. (1136).

New South Wales: Ebor in December; one specimen.

1584. *OCYSTOLA STENOPIS*, n. sp. (*στενωπισ*, narrow.)

♂. 14 mm. Head and thorax grey-whitish. Palpi with terminal joint one-half; whitish. Antennae grey-whitish; ciliations in male one-half. Abdomen grey. Legs grey; anterior pair fuscous. Forewings narrow, costa scarcely arched, apex rounded, termen very obliquely rounded; whitish with a few scattered grey scales; markings fuscous; discal dots minute, first at two-fifths, second at three-fifths; a slender line from costa before apex, at first inwardly oblique, before middle bent outwards, and thence slightly curved to before tornus; cilia grey-whitish. Hindwings and cilia pale grey.

New South Wales: Murrurundi in January; one specimen received from Dr. B. L. Middleton.

1585. *OCYSTOLA UNICOLOR*, n. sp. (*unicolor*, of one colour.)

♀. 20 mm. Head white. Palpi with terminal joint two-thirds; whitish. Antennae grey. Thorax pale grey. Abdomen dark grey; apices of segments grey-whitish; tuft whitish. Legs pale grey; posterior pair whitish. Forewings elongate, costa moderately arched, apex round-pointed, termen very obliquely rounded; grey-whitish slightly sprinkled with pale grey; cilia whitish. Hindwings pale grey; cilia whitish. To follow *O. monostropha* Meyr. (1137).

Queensland: Brisbane; one specimen.

1586. *OCYSTOLA XANTHOPEPLA*, n. sp. (*ξανθοπεπλος*, yellow-robed.)

♀. 20 mm. Head yellow. Palpi with terminal joint one-third; pale grey. Antennae grey. Thorax fuscous; apices of tegulae yellow. Abdomen fuscous. Legs grey; posterior pair ochreous. Forewings elongate, costa moderately arched, apex pointed, termen very oblique; yellow irregularly suffused with whitish; a fuscous dot on tornus; cilia pale grey, on tornus yellowish. Hindwings dark grey; cilia grey. To precede *O. illuta* Meyr. (1139). It is broader winged than this, and the short terminal joint of the palpi should be noted.

Queensland: Injune in April; one specimen.

1587. *OCYSTOLA SUBFLAVA*, n. sp. (*subflavus*, yellowish.)

♂, ♀. 14–15 mm. Head pale yellow. Palpi with terminal joint three-fifths; ochreous-whitish. Antennae grey. Thorax pale yellow; anterior margin fuscous. Abdomen grey. Legs grey; posterior pair ochreous-whitish. Forewings with costa moderately arched, apex obtuse, termen straight, oblique; pale yellow; markings grey; a costal streak from base to one-third; a line from one-third costa to one-third dorsum, slightly bent outwards in middle; an inwardly bent broader line from costa near apex to tornus; a terminal line thickened in middle; cilia yellowish-white. Hindwings and cilia grey. To follow *O. idiosticha* Turn (1158).

Queensland: Macpherson Rge. in February. New South Wales: Murrurundi in January; three specimens.

1588. *OCYSTOLA CASEICOLOR*, n. sp. (*caseicolor*, cheese-coloured.)

♂. 18 mm. Head and thorax pale yellow. Palpi with terminal joint one-half; pale yellow, external surface of second joint except apex fuscous. Antennae grey; ciliations in male 2. (Abdomen missing.) Legs whitish; anterior pair fuscous. Forewings narrow, posteriorly dilated, costa slightly arched, apex pointed, termen very oblique; pale yellow; minute fuscous dots at one-fifth and three-fifths; cilia pale yellow. Hindwings and cilia whitish. To precede *O. poliophracta* Turn.

Queensland: Macpherson Rge. (3,000 ft.) in November; one specimen received from Mr. W. B. Barnard.

1589. *OCYSTOLA METACHALCA*, n. sp. (*μεταχαλκος*, brassy posteriorly.)

♂. 16 mm. Head whitish; face lustrous silvery. Palpi with terminal joint four-fifths; whitish-grey, apex of second joint whitish. Antennae fuscous; ciliations in male 3. Thorax whitish-grey; anterior margin dark fuscous. Abdomen dark fuscous. Legs fuscous; posterior pair grey-whitish. Forewings narrow, costa moderately arched, apex pointed, termen very oblique; fuscous; markings whitish, broadly suffused; a large basal spot; a broad inwardly curved oblique median fascia; an erect mark from tornus

half across disc; a narrow line on upper two-thirds of termen; cilia fuscous. Hindwings dark brassy; cilia fuscous. To come before *O. episcota* Meyr. (1164).

Queensland: Stanthorpe in February (W. B. Barnard); one specimen.

1590. *OCYSTOLA LEPTOTYPA*, n. sp. (*λεπτοτυπος*, slenderly marked.)

♀. 15 mm. Head and thorax whitish. Palpi with terminal joint two-thirds; whitish, second joint except apex grey on outer surface. Abdomen grey. Legs whitish; anterior pair fuscous. Forewings narrow, costa slightly arched, apex rounded, termen obliquely rounded; white finely but unevenly sprinkled with fuscous, less so in middle of disc; markings fuscous; stigmata minute, first discal at one-fourth, second at three-fifths, plical before first discal, second discal connected by a streak with tornus; a slender line from costa before apex; inwardly oblique, angled inwards beneath costa, outwards in middle, and continued to tornus; a slight apical suffusion; cilia white. Hindwings and cilia grey-whitish. To follow *O. triticea* Meyr. (1165).

Queensland: Brisbane in August; one specimen.

1591. *OCYSTOLA TRISTICHA*, n. sp. (*τριστιχος*, three-lined.)

♂. 12 mm. Head dark fuscous; face white. Palpi with terminal joint three-fifths; whitish with three slender fuscous rings, subapical on second joint, median and subapical on terminal joint. Antennae grey; ciliations in male 1 and one-half. Thorax yellow, anterior margin dark fuscous. (Abdomen missing.) Legs fuscous with whitish rings; posterior pair almost wholly whitish. Forewings narrow, costa scarcely arched, apex pointed, termen very oblique; yellow; markings dark fuscous; a dot on base of costa and a second closely following; an outwardly curved line from one-third costa to two-fifths dorsum; a second broader line from two-thirds costa to tornus; a terminal line from apex not reaching tornus; cilia yellow, on apex dark fuscous. Hindwings and cilia pale grey. To be placed before *O. lochmaea* Turn. (1166).

Queensland: Injune in March (W. B. Barnard); one specimen.

1592. *OCYSTOLA EXQUISITA*, n. sp. (*exquisitus*, choice.)

♂. 11-12 mm. Head pale yellow. Palpi with terminal joint two-thirds; whitish. Antennae fuscous; ciliations in male 2 and one-half. Thorax yellow, anterior edge fuscous. Abdomen fuscous; tuft grey. Legs fuscous; posterior pair whitish. Forewings narrow, costa gently arched, apex pointed, termen very obliquely rounded; pale yellow; costal edge fuscous from base to one-fourth; a purple-fuscous line from one-fourth costa to one-fifth dorsum; a similar line from three-fourths costa to tornus, forming the margin of a triangular purple-fuscous blotch paler in centre; cilia pale grey. Hindwings and cilia pale grey. To follow *O. callisticha* Turn. (1167).

Queensland: Stanthorpe in January (W. B. Barnard); two specimens. Type in Queensland Museum.

1593. *OCYSTOLA LEUCOPLACA*, n. sp. (*λευκοπλακος*, broadly white.)

♀. 14 mm. Head white. Palpi with terminal joint three-fourths; white, outer surface of second joint except apex fuscous. Antennae grey. Thorax fuscous. Abdomen grey; tuft ochreous-tinged. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa gently arched, apex pointed, termen straight, oblique; fuscous; a broad sub-basal white fascia extending to one-fourth costa and two-fifths dorsum, leaving a fuscous basal fascia; disc irregularly sprinkled with white; posterior edge of fascia, a subterminal line, and a small terminal area dark fuscous; cilia dark fuscous. Hindwings grey; cilia whitish. I place this after *O. oridroma* Turn. (1173).

Queensland: Mt. Tamborine in November; Macpherson Rge. in December; two specimens.

1594. *OCYSTOLA ASTHENES*, n. sp. (*ασθενης*, weak.)

♀. 10 mm. Head and thorax ochreous-fuscous. Palpi with terminal joint two-thirds; whitish. Antennae pale grey. Abdomen fuscous. Legs grey-whitish; anterior pair grey. Forewings with costa almost straight, apex rounded, termen very oblique; ochreous-fuscous with suffused mixed whitish and ochreous-fuscous markings; a triangular mark from one-third costa ending half across disc; another from costa beyond middle ending above tornus; a third from costa near apex to termen just above tornus; a large spot or several small spots above dorsum about one-fourth; cilia pale grey. Hindwings and cilia grey. To follow *O. nigricincta* Meyr. (1334).

Queensland: Mt. Tamborine in November; one specimen.

1595. *OCYSTOLA HOMOXANTHA*, n. sp. (*ὁμοξανθος*, uniform yellow.)

♂, ♀. 15–20 mm. Head grey-whitish. Palpi with terminal joint three-fifths; whitish, external surface of second joint except apex whitish-grey. Antennae grey; ciliations in male two-thirds. Thorax yellow. Abdomen grey; tuft whitish. Legs fuscous; posterior pair grey. Forewings narrow, costa scarcely arched, apex pointed, termen very oblique; uniform deep yellow; costal edge whitish; cilia grey-whitish. Hindwings grey; cilia grey-whitish. To follow *O. amyloides* Meyr.

West Australia: Kalamunda, near Perth, in December and January (W. B. Barnard); twelve specimens. Type in Queensland Museum.

1596. *OCYSTOLA ISCHNOPHARA*, n. sp. (*ισχροφαρος*, narrowly cloaked.)

♀. 20 mm. Head whitish. Palpi with second joint exceeding base of antennae, terminal joint three-fifths; grey, apex and inner surface of second joint whitish. Antennae fuscous. Thorax grey. Antennae grey; apices of segments whitish. Legs grey; posterior pair whitish. Forewings narrow, elongate, costa gently arched, apex obtusely pointed, termen extremely oblique; whitish sprinkled with fuscous, appearing grey, markings dark fuscous; first discal at one-third, plical beneath and sometimes fused with it, second discal at two-thirds, double; a narrow fascia from four-fifths costa to mid-termen; cilia grey. Hindwings grey; cilia grey-whitish. This may be placed at the end of the genus.

Queensland: Brisbane in October; one specimen.

1597. *COESYRA GYPSOMERA* Low., *Trans. Roy. Soc. S. Aust.*, 1920, p. 62. This should follow *C. paragypha* Low. (1215). Antennal ciliations 2 and one-half.

1598. *COESYRA ALPHITOPIS*, n. sp. (*ἀλφίτωπις*, floury.)

♂. 19 mm. Head, thorax, and abdomen white. Palpi with terminal joint two-thirds; white, second joint except apex grey. Antennae whitish; ciliations in male 2. Legs grey; posterior pair whitish. Forewings subtriangular, costa slightly arched, apex round-pointed, termen oblique; white; an obscure minute fuscous discal dot at two-thirds; cilia grey-whitish. Hindwings and cilia grey-whitish. To follow *C. cretea* Turn. (1223).

1599. *COESYRA LAMBDA*, n. sp. (*λαμβδα*, a letter of the Greek alphabet.)

♂, ♀. 20–22 mm. Head and thorax white. Palpi with terminal joint four-fifths; outer surface of second joint except apex fuscous. Antennae grey; ciliations in male 1 and one-half. Abdomen grey; apices of segments and tuft whitish. Legs fuscous, posterior pair whitish-ochreous. Forewings posteriorly dilated, costa moderately arched, apex pointed, termen obliquely rounded; white; markings fuscous partly ochreous-tinged; a dark fuscous costal streak from base to one-fourth; a rather narrow fascia from three-fifths costa to one-third dorsum, with a small median posterior projection; a spot on dorsum beyond middle, sometimes connected with middle of median fascia; an outwardly curved subterminal fascia, preceded by two transversely placed dark fuscous dots; a small dentate terminal mark beneath apex; cilia white, bases barred with fuscous. Hindwings and cilia pale grey. To follow *O. gephyrota* Meyr. (1230).

Queensland: Injune in December; Talwood in November (W. B. Barnard); three specimens. Type in Queensland Museum.

1600. *COESYRA STENOMITA*, n. sp. (*στενομιτος*, with narrow threads.)

♂. 17 mm. Head pale yellow. Palpi with terminal joint one-half; pale yellow, outer surface of second joint except apex fuscous. Antennae fuscous; ciliations in male 1 and one-half. Thorax and abdomen fuscous. Legs fuscous; posterior pair ochreous-whitish. Forewings narrow, costa slightly arched, apex round-pointed, termen nearly straight, oblique; pale yellow; markings fuscous; a basal fascia broader on costa; slender oblique lines at one-third and two-thirds; the latter thickened on dorsum to reach tornus; a broad terminal line not reaching tornus; cilia pale yellow, on apex and tornus fuscous. Hindwings and cilia grey. This should come before *C. basilica* Meyr. (1264), which it much resembles, but differs in the fuscous thorax and basal fascia on forewing.

Queensland: Injune in September (W. B. Barnard); one specimen.

1601. *COESYRA MELANOMITA*, n. sp. (*μελανομιτος*, with black threads.)

♂. 16 mm. Head ochreous-yellow. Palpi with terminal joint one-half; whitish, external surface of second joint except apex fuscous. Antennae fuscous; ciliations in

male one-half. Thorax dark fuscous; patagia ochreous-yellow. Abdomen grey; tuft pale ochreous. Legs fuscous; posterior pair pale ochreous. Forewings with costa rather strongly arched, apex rounded, termen slightly rounded, oblique; yellow; markings and costal edge near base blackish; a narrow interrupted transverse line at one-third; an outwardly curved line from two-thirds costa to tornus, slightly expanded on margins; a terminal line broader towards apex; cilia yellow, on tornus fuscous. This may follow *C. basilica* Meyr. (1264).

Queensland: Carnarvon Rge. in December (W. B. Barnard) in January; one specimen.

1602. COESYRA STEREOMITA, n. sp. (*στερεομιτος*, with straight threads.)

♂, ♀. 16-18 mm. Head and thorax whitish-yellow. Palpi with terminal joint three-fifths; whitish. Antennae white with dark fuscous annulations; ciliations in male 1 and one-half. Abdomen grey. Legs grey; posterior pair whitish. Forewings with costa slightly arched, apex subrectangular, termen straight, slightly oblique; whitish-yellow; markings fuscous; a costal dot at three-fifths; a straight line from two-thirds costa to three-fourths dorsum; a terminal line; cilia fuscous; on tornus whitish. Hindwings and cilia grey. To follow *C. translatella* Wlk. (1268). New South Wales: Murrurundi in February; two specimens received from Dr. B. L. Middleton.

1603. COESYRA PLAGIOMOCHLA, n. sp. (*πλαγιομοχλος*, with an oblique bar.)

♂, ♀. 18-20 mm. Head pale yellow. Palpi with terminal joint two-thirds; pale yellow; outer surface of second joint pale fuscous towards base. Antennae grey; ciliations in male nearly 2. Thorax fuscous; patagia pale yellow. Abdomen grey. Legs, anterior pair fuscous; middle pair grey; posterior pair whitish-ochreous. Forewings narrow, costa gently arched, apex round-pointed, termen obliquely rounded; pale ochreous-yellow; an inwardly oblique bar from tornus half across disc, in some examples angled in middle and faintly continued outwards towards costa; sometimes a fuscous line on upper half of termen; cilia pale ochreous-yellow, on tornus fuscous. Hindwings and cilia pale grey. To follow *C. thiodes* Turn. (1278).

Queensland: Cunnamulla in September; seven specimens.

1604. COESYRA VIOLACEA, n. sp. (*violaceus*, tinged with violet.)

♂. 18 mm. Head pale ochreous. Palpi with terminal joint three-fifths; grey-whitish. Antennae fuscous; ciliations in male 6. Thorax and abdomen fuscous. Legs fuscous; posterior pair grey-whitish. Forewings rather narrow, costa gently arched, apex pointed, termen extremely oblique; deep yellow; a small triangular fuscous basal patch, broader on costa; a violaceous-grey patch occupying terminal two-fifths of wing, outlined by a slender fuscous line, its anterior edge nearly straight from three-fifths costa to two-thirds dorsum; cilia grey, bases grey-whitish. Hindwings and cilia grey. To follow *C. kershawi* Low. (1347).

Queensland: Duaringa in January (W. B. Barnard); one specimen.

1605. COESYRA COELOXANTHA, n. sp. (*κοιλοξανθος*, with hollowed yellow.)

♂. 19 mm. Head ochreous. Palpi with terminal joint three-fifths; fuscous, terminal joint whitish. Antennae fuscous; ciliations in male 3. Thorax pale fuscous; tegulae ochreous. Abdomen fuscous; tuft whitish-ochreous. Legs fuscous (posterior pair missing). Forewings with costa gently arched, apex obtusely pointed, termen oblique; rather deep yellow; a purple-fuscous basal blotch, its posterior edge straight from one-fourth costa to one-third dorsum; a purple-fuscous terminal blotch, its anterior edge strongly curved from apex to shortly before tornus; cilia fuscous. Hindwings and cilia grey. To come before *C. periculosa* Meyr. (1312).

Queensland: Talwood in November (W. B. Barnard); one specimen.

1606. CHEZALA ISCHNOPHANES, n. sp. (*ισχυροφανης*, narrow.)

♂. 20 mm. Head and thorax grey-whitish. Palpi with terminal joint one-half; pale grey. Antennae grey; ciliations in male 2. Abdomen grey; tuft grey-whitish. Legs fuscous; posterior pair whitish. Forewings narrow, costa straight to three-fourths, thence slightly arched, apex pointed, termen very obliquely rounded; white; markings fuscous; a costal streak from base nearly to apex, very narrow but broadening slightly beyond middle; a central streak from base to apex; cilia white. Hindwings and cilia grey-whitish. This may follow *C. rhadina*.

Victoria: Castlemaine in October (Dr. W. E. Drake); one specimen.

1607. LEISTOMORPHA METARRHACA, n. sp. (μεταρράκας, with a posterior patch.)

♀. 17 mm. Head, thorax, and abdomen fuscous. Palpi with second joint three times length of face (terminal joints broken off); fuscous. Antennae fuscous. Middle and posterior legs with tibial whorls of long hairs; fuscous. Forewings rather narrow, costa straight almost to apex, apex rounded, termen slightly rounded, oblique; fuscous; a narrow erect whitish mark from two-thirds dorsum reaching nearly half across wing; a whitish dot on base of dorsum; cilia fuscous. Hindwings fuscous; a broad whitish costal streak from base to four-fifths; cilia fuscous. Easily recognized by the whitish streak on hindwings. To follow *L. macrozancla* Turn. (1410).

New South Wales: Orange (Towac) in October (Dr. R. J. Tillyard); one specimen.

1608. CORMOTYPA TETRASTICHA, n. sp. (τετραστιχος, four-lined.)

♀. 22 mm. Head ochreous. Palpi with second joint twice length of face; ochreous-whitish. Antennae dark fuscous with white annulations. Thorax white; anterior margin fuscous. (Abdomen missing.) Legs pale ochreous. Forewings sub-oblong, costa straight except near base and apex, apex pointed, termen slightly sinuate, slightly oblique; white with four dark fuscous transverse lines; first sub-basal, broader on costa; second from two-fifths dorsum, not reaching costa; third from three-fifths costa to three-fourths dorsum; fourth subterminal; two or three dots on termen beneath apex; cilia white. Hindwings grey; cilia grey, on apex and tornus whitish. This may follow *C. mitrocosma* (1432).

West Australia: Kalamunda, near Perth, in December (W. B. Barnard); one specimen.

1609. CORMOTYPA TOXERES, n. sp. (τοξηρης, furnished with a bow.)

♀. 25 mm. Head pale yellow. Palpi whitish-ochreous, basal two-thirds of outer surface of second joint fuscous. Antennae grey. Thorax fuscous; patagia pale yellow. Abdomen grey; tuft whitish-ochreous. Legs fuscous; posterior pair pale yellow. Forewings with costa strongly arched to middle, thence straight, apex pointed, termen slightly sinuate, slightly oblique; pale yellow; an inwardly oblique fuscous basal fascia; an incurved purple-fuscous fascia from two-thirds costa to three-fourths dorsum, constricted in middle, dilated at each end; cilia fuscous. Hindwings grey, apex and termen suffused with ochreous; cilia grey. This should precede *C. fascialis* (1433).

Queensland: Injune in November (W. B. Barnard); one specimen.

1610. CORMOTYPA DREPANEPHORA, n. sp. (δρεπανηφορος, scythe-bearing.)

♀. 20 mm. Head ochreous-yellow. Palpi long, second joint exceeding vertex, terminal joint four-fifths; fuscous, inner surface of second joint whitish. Antennae fuscous. Thorax purple-fuscous. Abdomen grey; tuft ochreous. Legs fuscous; posterior pair ochreous. Forewings elongate, costa strongly arched, apex rectangular, termen nearly straight, slightly oblique; yellow; a fuscous costal streak broad at base, becoming narrow and indistinct beyond middle; a purple terminal blotch edged by a strongly curved fuscous line from near apex to three-fifths dorsum; cilia fuscous. Hindwings and cilia fuscous. Allied to *C. catachrysa* (1455), but without basal fascia, differently shaped terminal blotch, and considerably longer palpi.

Queensland: Carnarvon Rge. in January (W. B. Barnard); two specimens. Type in Queensland Museum.

1611. CORMOTYPA CAPNOCHROA Low., *Trans. Roy. Soc. S. Aust.*, 1920, p. 62. I have seen the type, which has an antennal pecten; but unfortunately I made no note on the palpi. This may follow *C. fusca*. (Adelaide.)

1612. CORMOTYPA MICROPASTA, n. sp. (μικροπαστος, minutely spotted.)

♂. 18 mm. Head and thorax grey. Palpi whitish, outer surface of second joint except apex fuscous. Antennae grey; ciliations in male 1. Abdomen pale grey. Legs grey; posterior pair whitish. Forewings with costa moderately arched, apex rounded, termen rounded, slightly oblique; grey-whitish with minute fuscous dots; first discal at one-third, plical slightly beyond, second discal about three-fifths; a series of dots from three-fifths costa obliquely outwards, angled above middle, thence parallel to termen, not reaching dorsum; cilia whitish. Hindwings pale grey; cilia white with pale grey basal line. Not near any other species, but may follow *C. capnochroa*.

West Australia: Albany in March (W. B. Barnard); one specimen.

1613. *TANYZANCLA PERIPHANES*, n. sp. (*περιφανης*, conspicuous.)

♂, ♀. 16-19 mm. Head orange-yellow. Palpi with second joint reaching base of antennae, terminal joint one-half; dark fuscous, internal surface and apex of second joint yellow. Antennae dark fuscous; ciliations in male 3. Thorax and abdomen dark fuscous. Legs dark fuscous; tarsal annulations and the greater part of posterior tibiae orange. Forewings elongate, moderately dilated, costa moderately arched, apex pointed, termen nearly straight, slightly oblique; dark fuscous; a large sub-basal quadrangular orange-yellow blotch extending nearly to costa; sometimes small suffused orange-yellow spots on costa at two-thirds and dorsum at three-fourths; cilia dark fuscous. Hindwings deep orange; apical half, terminal edge, and a streak from dorsum near base to termen near tornus dark fuscous; cilia dark fuscous. This should come before *T. helias* (1475).

Queensland: Macpherson Rge. (3,000-3,500 ft.) in December and January; five specimens.

1614. *TANYZANCLA SERICA*, n. sp. (*sericus*, silken.)

♀. 18-20 mm. Head ochreous-whitish. Palpi with terminal joint two-thirds; white, anterior edge fuscous. Antennae fuscous. Thorax fuscous, apices of tegulae and a posterior spot whitish. Abdomen grey. Legs fuscous; posterior pair ochreous-whitish. Forewings rather narrow, costa slightly arched, apex obtusely pointed, termen very oblique; glossy ochreous-whitish; a narrow fascia from tornus towards but not reaching two-thirds costa; followed by a varying amount of fuscous suffusion; cilia grey. Hindwings and cilia grey. This should follow *T. ocularis* (1513).

Queensland: Carnarvon Rge. in December (W. B. Barnard); two specimens. Type in Queensland Museum.

1615. *TANYZANCLA PHAEOXANTHA*, n. sp. (*φαιοξανθος*, dusky yellow.)

♂, ♀. 18-22 mm. Head yellow. Palpi with terminal joint three-fifths; fuscous, terminal joint and apex of second whitish. Antennae fuscous; ciliations in male 1. Thorax and abdomen dark fuscous. Legs fuscous; posterior pair whitish-ochreous. Forewings elongate, costa slightly arched, apex pointed, termen obliquely rounded; fuscous; suffused costal and dorsal yellow streaks; cilia fuscous. Hindwings fuscous; cilia fuscous, towards tornus yellowish. This should follow *T. gummosa* (1516).

Queensland: Bunya Mts. in October and December. New South Wales: Ebor in December; four specimens.

1616. *TANYZANCLA METACROCA*, n. sp. (*μετακροκος*, saffron posteriorly.)

♂, ♀. 18-20 mm. Head dark fuscous; on face mixed with whitish. Palpi with terminal joint one-half; white, apex of second joint fuscous. Antennae fuscous; ciliations in male 1 and one-half. Thorax white. Abdomen dark fuscous; tuft ochreous. Legs ochreous. Forewings with costa moderately arched, apex pointed, termen straight, oblique; dark fuscous with white markings; a narrow waved fascia from one-third costa to one-fourth dorsum; an oblong dorsal spot before tornus; a narrow triangular spot on three-fourths costa; some whitish scales before midtermen; cilia dark fuscous, on midtermen whitish-ochreous. Hindwings orange; a dark fuscous apical spot produced to tornus by a slender line; cilia dark fuscous. Nearest *P. thermochroa* Meyr.

Queensland: Injune in October and November (W. B. Barnard); two specimens. Type in Queensland Museum.

1617.† *TANYZANCLA ORGIASTIS* Meyr., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1620. This and the following are referred here conjecturally. (W.A.: York; Northampton).

1618.† *TANYZANCLA DIFFUSA* Luc., *Proc. Roy. Soc. Qd.*, 1901, p. 89 (Brisbane).

1619. *TANYZANCLA FUTILIS* Meyr., *Exot. Micro.*, ii, p. 383. I have examined the type. It resembles the male of *T. chionopectera* Meyr., the palpi being similar, but differs in its slight ochreous tinge, the shorter and broader forewings, the costal streak not closely approaching apex, and the antennae serrate towards apex with short ciliations (one-half). (Cairns.)

1620. *TANYZANCLA PROTECTA* Meyr., *Exot. Micro.*, ii, p. 383. Type examined. (Duaranga).

1621. *TANYZANCLA HOLOPSAMMA*, n. sp. (*ὄλοψαμμος*, all sandy.)

♂, ♀. 17-19 mm. Head pale brown. Palpi with terminal joint two-thirds; ochreous-whitish. Antennae pale brown; ciliations in male 2. Thorax pale brown with some

fuscous suffusion. Abdomen pale ochreous. Legs whitish-ochreous; anterior pair fuscous. Forewings with costa gently arched, apex round-pointed, termen obliquely rounded; pale brown with more or less fuscous sprinkling; markings fuscous; a small wedge on base of costa; discals approximated, first at two-fifths, second at three-fifths, plical beneath first; a suffused spot on three-fourths costa; some suffusion between second discal and tornus; cilia pale brown. Hindwings grey; cilia whitish or grey, sometimes ochreous-tinged.

North Queensland: Eungella in October; four specimens.

1622. *TANYZANCLA LITHOCHLORA* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1606 (Mt. Kosciusko).

1623. *TANYZANCLA METRIOPIS*, n. sp. (*μετριωπισ*, modest.)

♂. 22 mm. Head and thorax fuscous. Palpi with terminal joint one-half; uniformly grey. Antennae fuscous; ciliations in male 1 and one-half. Abdomen and legs grey. Forewings with costa gently arched, apex round-pointed, termen slightly rounded, oblique; whitish; cilia whitish. Hindwings broadly ovate; whitish-grey; cilia whitish. Differs from *T. lithochlora* in the fuscous head and thorax and the longer antennal ciliations (in *lithochlora* two-thirds).

Tasmania: Cradle Mt. in February; one specimen.

1624. *TANYZANCLA LEPTOPASTA*, n. sp. (*λεπτοπαστος*, lightly sprinkled.)

♂. 23 mm. Head and thorax ochreous-whitish. Palpi with terminal joint two-thirds; whitish, outer surface of second joint except apex fuscous. Antennae ochreous-whitish; ciliations in male 2. Abdomen ochreous-brown; apices of segments and tuft ochreous-whitish. Forewings with costa gently arched, apex pointed, termen obliquely rounded; ochreous-whitish with minute fuscous dots; first discal at one-fourth, plical slightly beyond, second discal at middle, double; a subterminal series of dots; cilia whitish. Hindwings broadly ovate; whitish; cilia whitish.

New South Wales: Mt. Kosciusko (5,000 ft.) in February; one specimen.

1625. *TANYZANCLA STICTOLOMA*, n. sp. (*στικτολωμος*, with spotted edge.)

♂. 24 mm. Head and thorax white. Palpi with terminal joint one-half; whitish, second joint except apex fuscous. Antennae grey; ciliations in male 1. Abdomen grey; apices of segments and tuft ochreous-whitish. Legs grey; posterior pair ochreous-whitish. Forewings with costa gently arched, apex round-pointed, termen very obliquely rounded; white; markings and costal edge near base dark fuscous; a minute streak on base of dorsum; another near base beneath costa; a dot on one-fourth costa; a series of terminal dots; cilia white. Hindwings and cilia pale grey.

Queensland: Bunya Mts. in March (W. B. Barnard); one specimen.

1626. *TANYZANCLA EUETHIRA*, n. sp. (*ευεθειρος*, long-haired.)

♂. 22-26 mm. Head and thorax whitish or grey. Palpi with terminal joint one-half; whitish. Antennae grey, towards base whitish; ciliations in male 4. Abdomen grey-whitish. Legs whitish; anterior pair fuscous. Forewings with costa gently arched, apex round-pointed, termen very obliquely rounded; whitish; costal edge fuscous near base; sometimes a minute fuscous discal dot at two-thirds; cilia whitish. Hindwings and cilia whitish. Distinguished by its much longer antennal ciliations from both *T. tyroxantha* and *T. lithochlora* (ciliations 1), which it closely resembles.

New South Wales: Tooloom in April (W. B. Barnard); three specimens. Type in Queensland Museum.

1627. *TANYZANCLA BAEOTYPA*, n. sp. (*βαιοτυπος*, slightly marked.)

♂. 22 mm. Head and thorax whitish. Palpi with terminal joint three-fifths; whitish. Antennae pale grey; ciliations in male 1. Forewings rather narrow, costa gently arched, termen nearly straight, oblique; whitish; costal edge near base fuscous; minute fuscous discal dots, first at one-third, second before three-fifths; a very faint sinuous fuscous subterminal line; a few fuscous scales in terminal area; cilia whitish. Hindwings and cilia whitish.

West Australia: Kalamunda, near Perth, in December (W. B. Barnard); one specimen.

THE SUBSPECIES OF *ANOPHELES AMICTUS* EDWARDS  
(DIPTERA, CULICIDAE).

By A. R. WOODHILL (A.A.M.C., Australia) and D. J. LEE, Department of Zoology,  
University of Sydney.

(Eight Text-figures.)

[Read 26th April, 1944.]

*Introduction.*

Edwards (1921) described the new species *Anopheles amictus* Edw. from Townsville, Queensland, and in the same paper recorded a similar specimen which varied from the type female in the banding of the hind tarsi ("female from Townsville, 2 :ii :1903, F. P. Dodd"). Later, Hill (1925), having examined considerable material from both Townsville and the Northern Territory, recorded both the type form of *A. amictus* and the variant mentioned above, which he queried as *A. amictus* and designated as "C". Since that time Hill's "type C" or "Hill's variety" have been names commonly used by Australian entomologists to differentiate this form from *A. amictus* Edw. (*sens. str.*) and, despite the very close relation between the two, the ease with which they may be separated and the complete absence of indeterminate specimens have given rise to a distinct and general impression that the two forms are both biologically and morphologically distinct.

One of us (A.R.W.) has had the opportunity of studying these forms in the Northern Territory, and, by a process of breeding series from individual females, has obtained convincing evidence that the two forms enjoy a constant distinction in morphology and a considerable measure of ecological separation. Further, the two forms, although having a wide distribution together, do appear to attain geographical separation in certain areas. For these reasons we have decided that the unnamed form is fully deserving of a subspecific\* name, and hence record herein the two subspecies *A. amictus amictus* Edw. and *A. amictus hilli*, n. subsp.

*ANOPHELES AMICTUS AMICTUS* Edwards, new status.

Edwards, F. W., 1921. *Bull. ent. Res.*, xii, 71 (*Anopheles amictus*).

*Type locality*: Townsville, Queensland.

*Types*: Type female and male in British Museum. It is not clear whether or not the male has been designated as an allotype.

It is unfortunate that we have had to rely on specimens of Edwards' species, determined by himself, rather than on the holotype, for our more detailed knowledge of this form, particularly in respect of the major diagnostic character which was not mentioned in the original or subsequent descriptions. On the other hand we have had before us the material used by Mackerras (1927) for his description of the larva of *A. amictus*, and hence the additional characters of importance detailed by us have been found in the actual specimens used in the preparation of the original larval description.

\* Recent authors (Huxley, 1942, p. 151 et seq.; Mayr, 1942, p. 33 et seq.) have indicated that a considerable body of evidence has accumulated substantiating the hypothesis that subspecies are developed by geographical separation. In the present case the origin of one or other subspecies by original geographical isolation is feasible, since it will be shown that only one has been found in New Guinea. Despite this, however, a further hypothesis, that the separation has been an ecological one, is not disproven, and as there is obviously much in common between geographical and ecological isolation of populations, it is considered that the use of the subspecific category is amply justified, even though any evidence of hybrid zones is lacking. Further, the practical value of such a nomenclature is considerable.

*Adult.*

In addition to the characters recorded by Edwards (1921, 1924) the most outstanding feature is the propleuron, which carries an elongate boss running transversely across the middle, from which arise from 10–14 strong bristles. The character which serves best to distinguish this subspecies from the following is the banding of the tarsi which is adequately described by Edwards.

*Larva.*

No mention of the thoracic chaetotaxy was made by Mackerras (1927) in his larval description. Here, however, we have found a most important character in the pleural hair-tufts. The pro-pleural, meso-pleural and meta-pleural groups have one of the long hairs (the outer one) plumose, in each group. Also the inner shoulder hair has no basal tubercle and possesses about eight branches (range 8–10). No constant differences have been discovered between the larva of this subspecies and *A. amictus hilli*, n. subsp., but the difference in the average number of branches of the inner shoulder hair is useful.

*Distribution.*—This subspecies has a wide distribution from the northern part of Western Australia across northern Australia and on the eastern part of Queensland to the New South Wales border. Specimens have been seen from the following localities: Northern Territory: Adelaide R.; Larrimah; Roper River Mission; Roper Bar; Delamere; Victoria River Downs. Queensland: Cairns; Mareeba; Townsville; Eidsvold; Augustus Downs; Chinchilla. New South Wales: Detman. Western Australia: Argyle Downs; Wyndham; Noonkambah.

## ANOPHELES AMICTUS HILLI, n. subsp.\*

*Type locality:* Adelaide River, Northern Territory of Australia.

*Types:* Holotype female, allotype male, 32 paratypes, 22 larval morphotypes and a series of eggs are lodged in the Museum of the Council for Scientific and Industrial Research, Canberra, A.C.T.

We have chosen for the type series of this subspecies an unusually wide range of material which has the distinction of being entirely the progeny of a single female. The eggs, larvae and adults were all produced from the one wild-caught female and so there can be no question of the discreteness of the series. The parent female is also included in the series of paratypes, the specimen, as one would expect, being somewhat too worn to be satisfactory for the holotype.

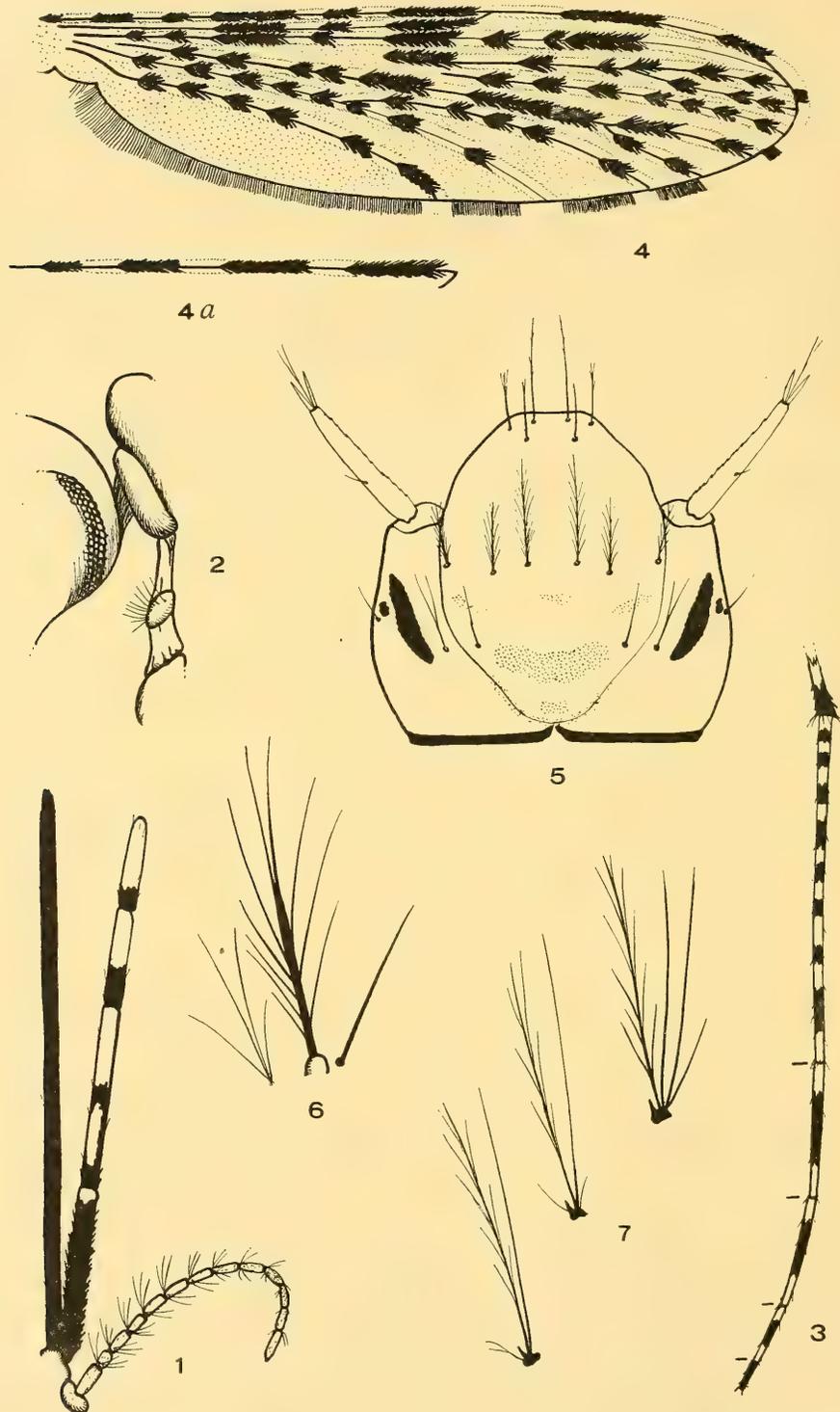
## DESCRIPTION.

*Female.*

*Head.* (Fig. 1.) Dorsally the head is clothed with upright-forked scales which are dark posteriorly and laterally, and white anteriorly. A frontal tuft of long white hairs projects forward between the bases of the antennae. The antennae are rather shorter than in other Australasian Myzomyias, except *A. amictus amictus*, being only about 0.6 the length of the proboscis, while the pedicel and flagellar segments I–VIII carry flat white scales. The palpi have segments III–V black basally with broad white apical bands, segment III has a dorsal patch of white scales on the black basal portion and segment II is black with a narrow white apical ring and some indistinct pale scales dorsally on the basal half. The proboscis is entirely dark scaled with dark brown labella.

*Thorax.* The scutum and scutellum carry broad white scales and dark hairs, while the pleurae are bare except for some scattered white scales on the sternopleuron and distinct upper mesepimeral and pre-alar bristles. The propleuron (Fig. 2) carries an elongate transverse boss which bears ten strong bristles and a few white scales. In

\* This new subspecies exhibits undoubted similarity to *A. incognitus* Brug 1931, *Geneesk. Tijdschr. Ned.-Ind.*, lxxi, 136, a species described from a unique larva only found at Merauke. However, the extremely well-developed seven-branched posterior clypeal hairs and the smooth, lanceolate fan leaves without filament, in contrast to the rather slender, elongate fan leaves of *A. amictus hilli*, which have a single notch on either side and a pronounced filament, make it impossible, at the present time, to regard the two forms as identical.



Figs. 1-7.—*Anopheles amictus hilli*, n. subsp. 1. Proboscis, palpus and antenna,  $\times 33$ . 2. Detail of propleuron,  $\times 38$ . 3. Hind tarsus,  $\times 20$ . 4. Wing,  $\times 34$ . 4a. A common variation of the proximal half of the costa,  $\times 34$ . 5. Head of larva,  $\times 65$ . 6. Shoulder hairs of larva,  $\times 250$ . 7. Pleural hairs of larva,  $\times 65$ .

the paratype series these bristles vary in number from 10 to 14. The halteres are pale with brownish scales covering the knob.

*Legs.* These have conspicuous patches of flat white scales on the coxae. The femora and tibiae are distinctly ringed and spotted with white scales. On the fore-leg, tarsus I has alternating black and white bands and an apical white band; tarsi II and III are dark in the centre with basal and apical white bands; tarsus IV is white and tarsus V dark. In the paratype series some specimens have a narrow black band or an indistinct dark patch in the centre of tarsus IV. On the mid- and hind-legs tarsus I has irregular white bands and spots and an apical white band; tarsi II, III and IV have apical and basal white bands and tarsus V is dark (Fig. 3).

*Wings.\**—The costa shows two pre-humeral dark spots divided by a pale spot, a distinct humeral dark spot, the pre-sector dark spot divided by a pale spot, and the median, pre-apical and apical dark spots are undivided. On the stem of R, below the humeral dark spot, are two small distinct dark spots. The remaining veins show numerous alternating dark and light spots as shown in Fig. 4. In numerous specimens of the paratype series the pre-sector dark spot is undivided (Fig. 4a). This is an extremely variable character.

*Abdomen.*—Tergite I bears a few pale scales, tergites II–VIII are densely covered with broad, flat yellowish scales with some darker scales on VIII. Sternites I–VII carry scattered broad white scales in ill-defined lateral patches.

#### *Male.*

The palpi are dark scaled, with a patch of white scales dorsally on the basal half of segment II and a small white patch apically. Segment III has scattered white scales on the basal half and a white dorsal patch on the apical half followed by a narrow black area. Segments IV and V have large white patches on the inner dorsal aspect.

In all other respects the type male is similar to the female, except that tarsus IV of the fore-legs is dark with a few indefinite pale scales, and there is a slight difference in the abdomen in that tergite VIII has white instead of yellow scales. In the paratype series, however, male specimens possess fore- and mid-tarsi corresponding entirely with the female, and the wings also exhibit the same variations as recorded for the female paratypes.

*Genitalia.* No distinguishing features have been found and only a detailed comparative study of large series of this and related species would be likely to reveal any differential characters.

#### *Larva. (Description from the morphotype series.)*

*Head.* (Fig. 5.) The inner and outer anterior clypeals are usually frayed or weakly branched or more rarely simple, the outer anteriors being 0.5 to 0.75 as long as the inner anteriors. The posterior clypeals are usually simple, rarely bifid or trifid at the tip and project well beyond the anterior margin of the head, being about 0.15 as long as the inner anteriors. The inner suturals are simple or bifid and the outer suturals simple, bifid or trifid.

*Thorax.* The shoulder hairs (Fig. 6) have their bases distinctly separated with the inner hair arising from a simple alveolus without any tubercle while the middle hair has a somewhat weakly developed basal tubercle carrying a blunt spine. The inner hair is weakly developed, with about four branches (range 1–6).

The pleural tufts each bear one long plumose hair (Fig. 7).

*Abdomen.* Tergal plaques are present on segments I–VIII with small median accessory tergal plaques on segments III–VII. Palmate tufts occur on segments II–VII. The median plate of the scoop is broadly rounded anteriorly without any lateral projections.

#### *Egg.* (Fig. 8.)

The exochorion is entirely rugose, and a flat white waxy frill projects laterally and rests on the surface of the water. When removed from the water this frill may collapse and adhere to the dorsal surface. The approximate length is 0.61 mm. and the approximate maximum breadth, exclusive of floats is 0.16 mm.

\* The terminology used in referring to the wing spots is that used by Gater, 1935, p. 3.

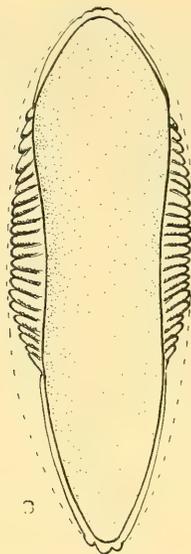


Fig. 8.—*Anopheles amictus hilli*, n. subsp., egg,  $\times 115$ .

*Distribution.*—This subspecies is widely distributed over the area where *A. amictus amictus* occurs but has also been recorded from Merauke in Dutch New Guinea. Specimens have been seen from the following localities: Northern Territory: Darwin; Adelaide R.; Margaret R.; Roper R., 59 miles E. of Mataranka; Roper Bar; Crocodile Point (Daly R.); Brocks Cr., Daly R.; Boorooloola; Koolpingah; Marrakai Station. Queensland: Lawn Hill (Saville Plain); Cairns; Townsville; Normanton; Brisbane. New South Wales: Larvae belonging to this subspecies or *A. amictus amictus* have been seen from Casino. Unfortunately the shoulder hairs were damaged so the identification must remain tentative. Western Australia: Wyndham. New Guinea: Merauke.

It will be seen from the descriptions that the two subspecies *A. amictus amictus* and *A. amictus hilli* are very closely related, and in the adult stage can only be differentiated by the banding of the hind tarsi. The larvae are also closely similar but appear separable on the average number of branches of the inner shoulder hair.

*A. amictus hilli* is frequently found breeding in brackish water even up to a salinity of 4.2%. Although it is also found inland in fresh-water, the coastal brackish water habitat is the more frequent. Records of *A. amictus amictus* from brackish water are very unusual and to our knowledge confined to one or two instances at Townsville.

A considerable amount of material has been examined from Merauke and only *A. amictus hilli* has been seen from there. Older records of *A. amictus* (Swellengrebel and Rodenwaldt, 1932, p. 198) from Dutch New Guinea also obviously refer to the subspecies *hilli*.

#### Acknowledgment.

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SOME NEW RECORDS AND NEW SYNONYMY OF AUSTRALIAN  
SPECIES OF *ANOPHELES* (DIPTERA, CULICIDAE).

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University of Sydney.

[Read 26th April, 1944.]

Records of the distribution of two species, previously unrecorded on the mainland of Australia, are herein presented. These are *Anopheles meraukensis* Venhuis and *Anopheles novaguinensis* Venhuis. Both species were originally described from Dutch New Guinea, the latter as *A. punctulatus* var. *novaguinensis*. We have, however, raised this variety to specific rank.\*

Also established is certain new synonymy of *Anopheles annulipes* Walker and *Anopheles novaguinensis* Venhuis.

*ANOPHELES MERAUKENSIS* Venhuis.

Venhuis, W. G., 1932, *Geneesk. Tijdschr. Ned.-Ind.*, lxxii, 1040.

———, 1932, loc. cit., 1043.

Soesilo, R., and Schoonheydt, L. J., 1932, loc. cit., 1044.

Type locality: Merauke, Dutch New Guinea. Type larva, female and male adults in Section for Malaria Control of the D.V.G. at Batavia-Centrum.

*A. meraukensis* in Australia.

Credit is due to Dr. G. M. Heydon for first recognizing the existence of a distinct species of *Anopheles* in Cairns in July, 1942. Dr. Heydon later described spontaneously to one of us the distinctive scale pattern of the venter of specimens which were taken in houses in Cairns and which he correctly considered to be distinct from *A. amictus*. Later examination of specimens taken in collections at Cairns at the time of Dr. Heydon's observations revealed definite *A. meraukensis*. The occurrence of *A. meraukensis* in the Northern Territory was first established by the authors early in 1943.

At first the larvae of this species were confused with those of *A. annulipes* Walk. and the adult with that of *A. amictus* Edw. When, however, the larva-adult correlation was established it was obvious that a distinct species, which one of us was able to identify from the literature as *A. meraukensis*, was involved.

Further study revealed the prevalence and distribution of this species in northern Australia and also threw further light on its differential characters and variability.

Venhuis considered the following to be the important characters of the few specimens he was able to examine:

- “1. The dorsum of the abdomen is covered with golden scales as in *A. amictus*.
2. The antennae are unusually broad at the base, as is the case in *A. amictus* but there are white scales on only one segment while in *A. amictus* there are white scales on the first nine segments.
3. Tarsi II to V inclusive of the hind leg have no basal rings as is the case in *A. amictus*.”

The first character we have found constant. The second may be confusing as white scales may be present on segments beyond the first flagellar segment of the antennae in *A. meraukensis*, although when this is so, they are smaller and less conspicuous. The

\* In “Keys to the Anopheline Mosquitoes of the World”, published by the American Entomological Society, 1943, p. 140, Russell, P. F., Rozeboom, L. E., and Stone, A., have cited Venhuis' variety as a subspecies, without comment.

third character does serve to distinguish *A. meraukensis* from the form of *A. amictus* found in Merauke but would not distinguish *A. meraukensis* from *A. amictus* Edw. (*sens. str.*), a form which so far has been recorded only from the mainland of Australia.

Beyond these characters, we have found that *A. meraukensis* is readily distinguishable from all forms of *A. amictus* on the distribution of the pale scaling of the abdominal sternites. In *A. amictus* these pale scales are abundant on the mid-ventral line, and, on the more distal segments (IV-VII) are, to some extent, grouped in lateral patches but the boundaries are ill-defined. In *A. meraukensis* the ventral abdominal scaling is characteristically in the form of small rounded lateral patches of pale scales on segments II-VII.

A further outstanding distinction is found in the prosternum. In *A. meraukensis* this is flat anteriorly and bears one to three strong bristles; in *A. amictus*, on the other hand, this structure has an elongated boss carrying 10-14 hairs and a variable number of broad white scales.

*Distribution.*—*A. meraukensis* has now been recorded from many places in the Northern Territory extending from near Darwin to Larrimah on the North-South Road and eastward to Groote Eylandt; and also from the Cairns-Townsville area on coastal Queensland.

Northern Territory: Adelaide R., iii.43, iv.43, v.43; Larrimah, iv.43; Blackfellow's Cr., Reynold's R., xi.42 (A.R.W.); Batchelor, iv.43 (Powell); Wynellie, x.43; Oenpelli, v.43; Daly R., v.43; Katherine, Roper Bar, vi.43; Roper R. Mission, vi.43 (A.R.W.); Groote Eylandt, ix.43 (J. Henry). Queensland: Cairns, vii.42 (A.R.W.); Townsville, vii.43 (G. Pasfield); Mareeba, viii.43 (D. Cameron).

Representative specimens have been deposited in the Museum of the Council for Scientific and Industrial Research, Division of Economic Entomology, Canberra, A.C.T.

*Note:* As the original description of *A. meraukensis* is in Dutch and not readily accessible, we present in Appendix A a full translation of Venhuis' description.

#### ANOPHELES NOVAGUINENSIS Venhuis.

##### *New Synonymy.*

- (i). *A. punctulatus* var. *novaguinensis* Venhuis, 1933, *Geneesk. Tijdschr. Ned.-Ind.*, lxxiii, 203. Soesilo, R., and van Hell, J. C., 1933, loc. cit., 207.
- (ii). *A. derricki* Taylor, 1943, *Proc. Linn. Soc. N.S.W.*, lxviii, 155 (*partim*, female only).  
*Type locality:* Irvinebank, Queensland.
- (iii). *A. breinli* Taylor, 1943, loc. cit., 156. *Type locality:* Irvinebank, Queensland.

*Type locality:* The middle tract of the Merauke River, Dutch New Guinea, between the compound Kakajoe and Donggeap. Type larva, female and male adults in Section for Malaria Control of the D.V.G. at Batavia-Centrum.

Although this species was originally described as a variety of *A. punctulatus* by Venhuis we have concluded that the form, in our interpretation, is remarkably distinct from other Australian species, including *A. punctulatus*, and hence is best considered as a separate species. The particular reasons for this decision are made clear below.

- (i). *A. novaguinensis* in Australia.

Specimens collected in the Northern Territory, because of their very dark appearance, suggested the possibility of *A. novaguinensis*; then, when larvae were obtained which closely resembled the description of the larva of this species and were correlated with these adults, a tentative determination was made of the Northern Territory form as *A. novaguinensis*.

Later examination of a large number of larval and adult specimens revealed that while this common Northern Territory species agreed in all respects with the original description, certain characters varied far more than was indicated originally. The feature which makes the adult of this species so distinct from any other Australasian form is the white scaling of the mesonotum which is restricted to a central longitudinal strip covering about half the width of the mesonotum, leaving the lateral areas bare of scales. As only a very limited series of bred specimens was available for the original description it seems highly probable that this character was overlooked by Venhuis.

The feature which was found more variable than the description suggested was the palpal ornamentation, particularly that of the fourth segment, which we found to vary from completely black to almost two-thirds white in the progeny of a single female of the species.

It should be noted, too, that in the pro-, meso- and meta-plural hair tufts of the larva, one of the long hairs of each tuft is distinctly branched. This branching is described by Soesilo and van Hell but the Australian specimens frequently exhibit it more clearly than indicated by their figure.

It is of considerable interest to note that Hill (1925)\* figures as a variation of *A. punctulatus* var. *moluccensis* a wing which undoubtedly correctly belongs to *A. novaguinensis*. The locality from which the specimen studied by Hill was obtained is doubtful but is most likely either the Northern Territory or New Britain. In any case this is without question the first known record of this distinct species.

*Distribution*.—*A. novaguinensis* has been found commonly in the Northern Territory from Darwin to Pine Creek and in certain other isolated localities. It is also recorded from Irvinebank, north Queensland, by Taylor under the names *A. derricki* and *A. breinli* (see below). Recently it has been found at Jacky Jacky, north Queensland, xi.43 (F. Chippendale).

Northern Territory: Adelaide R., ii.43, iii.43 (A.R.W.); Pine Creek, iii.43 (Hegener); 38 m. S. of Darwin, iii.43 (Wilde); Larrakia, iii.43 (N. Johnson); Roper R. Mission, vi.43 (A.R.W.); Port Keats, vi.43 (Fox).

Representative specimens have been deposited in the Museum of the Council for Scientific and Industrial Research, Division of Economic Entomology, Canberra, A.C.T.

*Note*: For a full translation of Venhuis' original description of *A. punctulatus* var. *novaguinensis* see Appendix B.

(ii). *Anopheles derricki* Taylor (*partim*, type ♀ only).

For reasons detailed above, we have identified a common Northern Territory Anopheline as *A. novaguinensis* Venhuis. The most striking characters in our interpretation of this species are the thoracic scaling and the wing pattern. The mesonotal character is described above and we find that in this respect the type female of *A. derricki* agrees fully with our description. Furthermore, in *A. novaguinensis* the wing is considerably darker than in other *Myzomyias* and the most striking feature of this is the long, uninterrupted line of black scales on the media instead of the spotting of alternating black and white patches common to other species. In this respect also the type of *A. derricki* agrees both with the original description and with the Northern Territory specimens of *A. novaguinensis*. The completely black fourth palpal segment described by Taylor is admittedly at variance with Venhuis' description, but, as noted above, this is an observed variation in the species. It is logical, therefore, to synonymize the name *A. derricki*, in so far as the description of the female is concerned, with *A. novaguinensis*.

(iii). *Anopheles breinli* Taylor.

Examination of the type of this name revealed that the lateral margins of the mesonotum were bare of scales and in all other respects as well, particularly wings and palpi, this specimen is to be identified with *A. novaguinensis* and the name thus becomes a synonym of that species.

ANOPHELES ANNULIPES Walker.

*New Synonymy*:

- (i). *A. perplexus* Taylor, 1943, Proc. Linn. Soc. N.S.W., lxxviii, 153. *Type locality*: Not stated.
- (ii). *A. perplexus* var. *persimilis* Taylor, 1943, loc. cit., 155. *Type locality*: Irvinebank, Queensland.
- (iii). *A. derricki* Taylor, 1943, loc. cit., 155 (*partim*, male only). *Type locality*: Irvinebank, Queensland.

\* Hill, G. F., 1925, *Proc. Roy. Soc. Vict.*, xxxvii, plate vi, fig. 6b.

(i). *Anopheles perplexus* Taylor.

We have examined the holotype and allotype of this name and find them to be identical with *Anopheles annulipes* Walk.; the name *A. perplexus* is, hence, a synonym of *A. annulipes*. The evidence on which this conclusion is based is as follows:

(a). The only feature which might appear to separate *A. perplexus* from *A. annulipes* is the presence of scaling on the abdominal tergites, but an examination of a large number of specimens of *A. annulipes* (800 at least) has convinced us that in this species any amount of abdominal scaling may be present between the following extremes: (i) Scales only on tergites VI and VIII and on sternite VIII, and (ii) dense scales on tergites II to VIII and some scales on sternites V to VIII. (This latter extreme is that which occurs in the type of *A. perplexus*.) Further, one of us (A.R.W.) has bred these densely-scaled forms in the Northern Territory (the type locality of *A. perplexus*) and found that the larvae of this form are identical with those of *A. annulipes*. Furthermore, both typical *A. annulipes* and the *A. perplexus* variant have been bred from the same breeding site. This observation has some significance in view of the fact that populations of restricted breeding sites frequently conform to a particular morphological form.

(b). Certain features of the description might cause doubt in the minds of workers having to rely on the text and figures alone for an interpretation of the status of *A. perplexus*. In the verbal description it is stated that there is a small patch of flat white scales on the metathorax. It would be unusual if this were so, but actually in the type such scales are not present. The figure of the female palpi does not indicate the presence of a median internal dorsal patch of white scales on the second palpal segment, but as in typical *A. annulipes*, these do occur in the type of *A. perplexus*. The male palp as illustrated appears to have complete white rings in the centres of the second and third segments, but an examination of the allotype showed that these segments are normally ornamented with irregular white scaling dorsally which is not continuous in a ring beneath the palpus.

(ii). *Anopheles perplexus* var. *persimilis* Taylor.

This variety is stated to differ from the typical form in the marking of the palpi and the wings.

Examination of the type revealed that the palpi are identical with those of *A. perplexus* (as illustrated in Fig. 3a, but not as described in the text).

The wing is rather darker on the costal margin than is common in *A. annulipes* but nevertheless falls within the range of variation found in this species. The lack of a black spot at the base of the radius is typical of *A. annulipes* and hence this new variety must also be relegated to synonymy with *A. annulipes*.

(iii). *Anopheles derricki* Taylor (*partim*, allotype ♂ only).

The synonymy of this name is somewhat more complex since two species have been confused in the type series of one male and one female specimens. The holotype female is identical with our interpretation of the species *A. novaguinensis* Venhuis and the allotype male is the ubiquitous Australian *A. annulipes*.

No detailed description of the allotype male is given by Taylor apart from figures of the terminalia and palpus. The specimen differs from the type female in two major characters. First, the mesonotum is completely clothed with white curved scales instead of having the lateral margins bare as in the female. Secondly, the wing markings are very distinct from those of the holotype, particularly the media which bears an alternating series of black and white scales as in the wing illustrated (Fig. 4c). These characters suffice to show that the male specimen is not identical with the female, and all other features of the male are typical of *A. annulipes* and we must thus record *A. derricki* (in part, male) as synonymous with *A. annulipes* Walk.

*Acknowledgments.*

This paper is published by permission of the Director-General of Medical Services. We desire to record our appreciation of the assistance given us by Miss B. Hockey and

Dr. J. P. A. van Leent in the translations from the Dutch, and our indebtedness to the Director, School of Public Health and Tropical Medicine, University of Sydney, for permission to examine the types of Mr. Taylor's new species.

## APPENDIX A.

*Anopheles meraukensis* Venhuis 1932. Translation of original description. *Geneesk. Tijdschr. Ned.-Ind.*, lxxii, 1040-42.

*Description of Larva.*

"Length: 5.5 mm. Colour: dark brown to black, the head especially being very dark. Laterally the thorax is much paler, so that the larva appears very slender, just as in *A. bancrofti* and often in *A. amictus*. Pale areas are present on the first thoracic segment and on abdominal segments III and VIII, sometimes also on segment V. The pale areas are not very distinct.

*Head.* "Antennae: At about one-third of the length there is a small unbranched lateral hair. The tip hair is divided into 2-4 branches at half its length.

"Clypeus. Inner clypeal hairs: these are far apart and have lateral hairs on the upper half, of which the lowest ones are mostly coarse and are themselves laterally haired. Outer clypeal hairs: these stand some distance back and are very strongly branched. The short stem usually divides into two or three branches, which form together about 30 to 35 stiff straight branches. Posterior clypeal hairs: these are situated not quite so far back as the distance apart of the inner clypeal hairs, and are situated a little inside the outer clypeal hairs. They have six or seven branches. Frontal hairs: nothing particular. Inner hairs with two or three branches, rarely simple. Outer hairs situated definitely to the front, with four or five branches.

*Thorax.* "Shoulder hairs: the strongly branched centre and inner shoulder hairs have heavy roots which are deformed. The unbranched outer hair is not planted on the root of the centre hair. Fans: on the third thoracic segment a pair of rudimentary fans, sometimes hard to see, with about twelve leaves.

*Abdomen.* "On the first abdominal segment a small rudimentary fan with about six small leaves. On the remaining segments are well-developed fans with 20-24 leaves. Form of the fan leaf: serrate, sometimes dentate, with sharp point without prolongation. Sometimes with pigmented stains. Comb: this resembles very much that of *A. fuliginosus*, as described by Dr. Walch and Dr. Soesilo in the Mededeelingen van den D.V.G. XVIII, 1929, No. 3. It does not resemble the comb of *A. amictus*.

*Description of the Female.*

*Head.* "Proboscis: this is completely black. Palpi\*: as long as proboscis, wholly covered with broad scales. The first segment is almost dark, only at the top there is a small white ring and in the middle on the inside a few white scales. The second segment is dark at the base for little more than half, in the middle of which field there are a few white scales. The distal half is white. The fourth segment is totally white, with the exception of a very small narrow black ring at the base. Antennae: the basal portion is, just as in *A. amictus*, broader than in other Anophelines, while the antenna has the usual width at the distal portion. The first section only is littered with broad white scales and white hairs, the other sections have hairs only. Head: in front between the eyes are placed long white hairs, behind those are broad white scales, then white forked scales and behind those black forked scales.

*Thorax.* "Prothoracic lobes: a bundle of broad black scales are present on these and some black hairs. Mesonotum: grey, completely covered with broad white scales; on both sides and behind there are also hairs. Scutellum: some broad white scales and black hairs.

*Abdomen.* "The first segment shows dorsally some yellow scales and black and yellow hairs. All segments are, just as in *A. amictus*, closely and regularly covered with broad gold-coloured scales; between the scales are yellow and black hairs. Ventrally the first four segments show sparsely scattered yellow and white scales, in between them a fair amount of yellow and black hairs. Further behind, the amount of yellow scales increases, while here the white scales in the middle of the front margin of each segment are united into groups. At the very end are black scales.

*Legs.* "Femur, tibia and tarsus I of all legs are stained light-yellow, and in addition to this, tarsi II, III, and IV of the hind leg have some light scales in the middle part. Tarsi I to IV inclusive of all legs, have on the apex a yellow band, while there are rings at the base of tarsi II to V inclusive of fore- and mid-leg, these being absent on the hind leg.

*Wings.* "The top of the first fork cell is clearly closer to the base of the wing than is the top of the second fork cell. Costa: at the base a very small dark stain and two similarly small stains, towards the apex a large stain, which corresponds with a stain on subcosta and first longitudinal vein. Towards the top is a very large stain, corresponding with a stain on subcosta, first and second longitudinal veins, followed up by a big stain, which is opposed by a stain on first longitudinal vein, and very near to the top another big stain opposite a stain on the first longitudinal vein. Subcosta with two large black stains. First longitudinal vein: at base a small stain, then a large stain, and then a stain, not quite so large opposite the very large stain

\* First segment is in reality segments I and II together and so second segment in this description is really segment III, third segment is segment IV and fourth segment is segment V.

on costa and subcosta, then again two or three small stains, then a relatively large stain, then a small stain and then at last sub-apically a large stain. Second longitudinal vein: on the stem one large and two small stains; the upper branch of the fork has two groups of three small stains, the lower branch has six disseminated small stains. Third longitudinal vein: seven stains. Fourth longitudinal vein: the stem has six small stains and one large stain just in front of the bifurcation. On both branches of the fork one fairly large and two small stains. Fifth longitudinal vein: on the stem four or five small stains, on both branches of the fork four small stains. Sixth longitudinal vein: 6 to 8 small stains. Fringe: this is dark between the joints of all branches, except between the first longitudinal vein and the upper branch of the second longitudinal vein and except between the lower branch of the second and third longitudinal veins."

#### APPENDIX B.

*Anopheles punctulatus* var. *novaguinensis* Venhuis 1933. Translation of original description. *Geneesk. Tijdschr. Ned.-Ind.*, lxxiii, 203-206.

#### Description of Larva.

"Length: 5 mm. Colour: dark brown, sometimes more transparent. Spots were not seen on thorax or abdominal segments.

*Head.* "Antennae: at about one-third the length there is a small unbranched lateral hair. Clypeus: inner clypeal hairs—these are distinctly further apart than they are from the outer clypeal hairs (20-7) and have distinct lateral hairs. Outer clypeal hairs: these are half as long as the inner clypeal hairs (30-60) and have coarse lateral hairs. Posterior clypeal hairs: these are about one-third as long as the inner clypeal hairs (19-60) and have three to five branches. They are situated about their own length behind the inner clypeal hairs, somewhat further apart than these. Occipital hairs: inner occipital hairs two-branched; outer occipital hairs with four to six branches.

*Thorax.* "Shoulder hairs: the inner and centre hairs have heavy roots which have not grown clearly. The centre hair has about 12-14 lateral branches, the inner hair 10-12 branches. The unbranched outer hair is not planted on the root of the centre hair. Fans: on the third thoracic segment are a pair of rudimentary fans with four to five small leaves.

*Abdomen.* "On the first abdominal segment is a rudimentary fan with about ten small leaves. On the second a small fan with about 18 leaves. On the remaining segments well-developed fans with about 20 leaves. Form of the fan leaf: serrated with a small point without filament; unpigmented. Pecten: this resembles closely that of *A. fuliginosus* but not that of *A. punctulatus*.

#### Description of Female Adult.

*Head.* "Proboscis: this is completely black. Palpi\*: the same length as the proboscis. The first segment is almost completely dark, with a narrow white ring at the tip. The second segment is dark for about the basal half, the apical half is completely white. The third segment is dark for about the basal half, the rest white. The fourth segment is quite white except for a narrow dark basal ring. On the dark palpal segments there are no yellow or white scales. Antennae: on the base and the first segment there are some white scales. Head: in front between the eyes there are long white hairs, behind these broad white scales, then wide white fork scales and behind these a very few black fork scales.

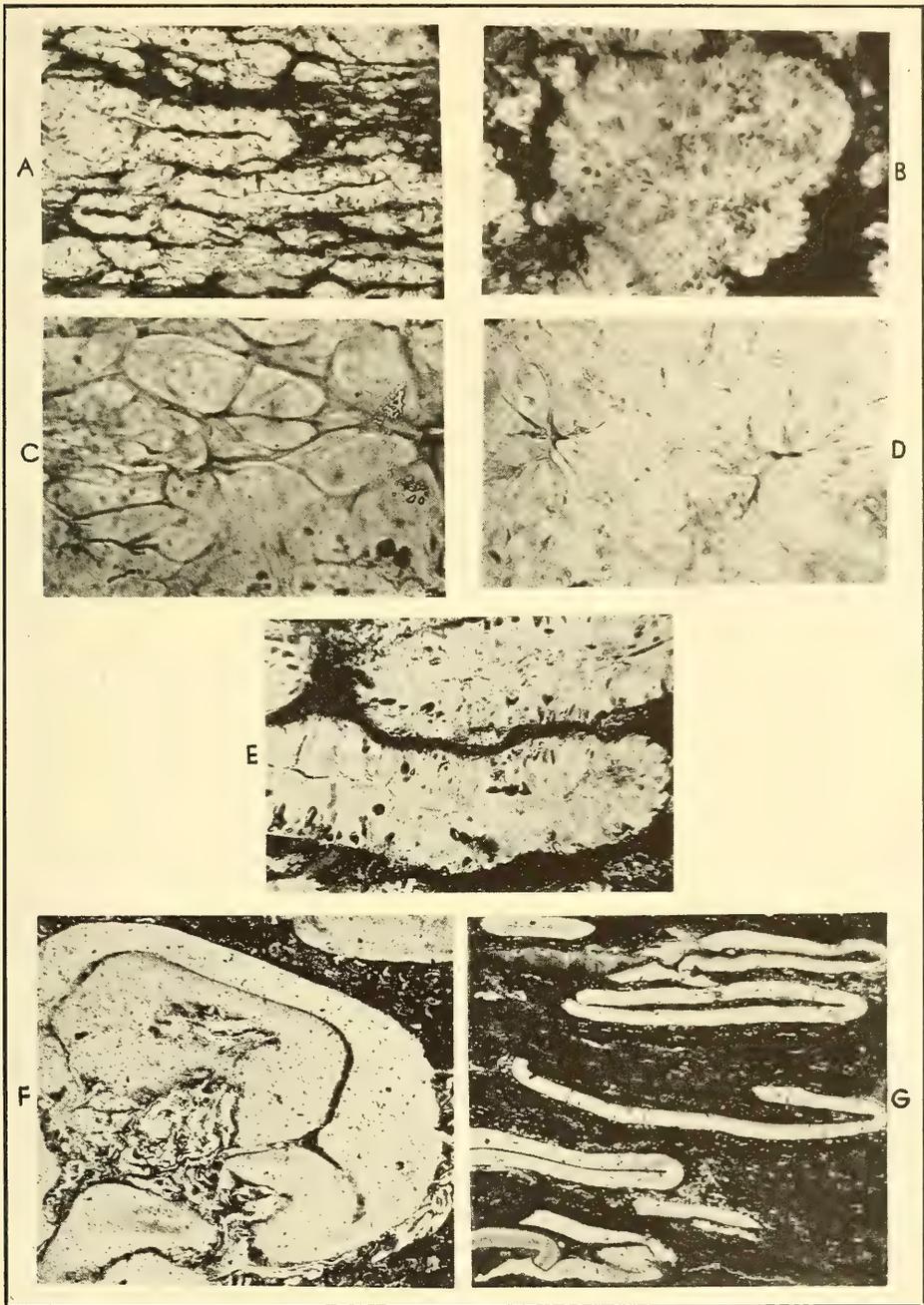
*Thorax.* "On the prothoracic lobes a group of black scales and hairs. Mesonotum brown-grey, covered with white scales and some yellow-brown hairs.

*Abdomen.* "Only hairs except on the last segment where there are some white scales. On the hypopygium black scales. Ventrally on the abdomen no scales.

*Legs.* "Femur, tibia, and tarsus I of all legs stained. Tibia, and tarsi I to IV of all legs have very narrow apical white bands. Tarsus V is completely dark. Basal bands are present on none of the legs.

*Wings.* "The tip of the first fork cell is closer to the wing base than that of the second. The whole wing gives a darker impression than in *A. punctulatus* var. *moluccensis*. Costa: basally two equally small stains, followed by four large stains of which the second is very large. Subcosta: two large stains opposite the first and second large costal stain. First longitudinal vein: four large stains opposite those of the costa. Between the first and second stain there is one small stain, while sometimes the third stain is divided in two. Second longitudinal vein: on the stem two long stains, the bifurcation is pale; on the first branch a long and a short stain, on the second branch two to four small stains completely or almost completely merged. Third longitudinal vein: six small stains, often almost merged. Fourth longitudinal vein: on the stem two long spots, the bifurcation is pale, on the first and the second branch two very large stains. Fifth longitudinal vein: on the stem there follow in succession a small and a large stain, the latter of which usually extends to the second branch. On the first branch four stains, which are sometimes merged two and two together, on the second branch a small and a large stain. Sixth longitudinal vein: four stains of which the last two are long. Fringe: This is dark between the terminations of all veins except between the first longitudinal vein and the first branch of the second longitudinal vein and between the second branch of the second longitudinal vein and the third longitudinal vein. Further there are pale patches at the termination of all veins except those of the sixth longitudinal vein."

\* See footnote on page 71.



Origin of the New South Wales Torbanites.



## NOTES ON AUSTRALIAN ORCHIDS.

By the Rev. H. M. R. RUPP, B.A.

[Read 28th June, 1944.]

## DIURIS PUNCTATA Sm. var. SULFUREA, n. var.

Sepalum dorsale et petala lateralia sulfurea; sepala lateralia pallida; labellum fere aurantiacum.

Dorsal sepal and lateral petals clear sulphur yellow; lateral sepals pale green; labellum darker than the other segments, almost orange.

Green Valley, Guyra, N.S.W., T. P. Skinner, x.1936 and x.1943.

*Diuris punctata* is a variable species, but a sulphur-coloured form is so distinctive that it merits a varietal name. Typically the flowers are lilac or lavender; occasionally they are purple, or in some localities are so faintly coloured as to be mistaken for *D. alba* R.Br. Through the kindness of the Rev. E. Norman McKie, Guyra, I received sulphur-coloured flowers from Mr. Skinner in 1936. I thought it possible that they were due to some "freakishness" arising out of seasonal conditions, but two beautiful specimens sent in October, 1943, satisfied me that this cannot be the case. The flowers are of good size, and have a perfume like the old-fashioned *Iris germanica*. The typical form has this perfume occasionally, but in most New South Wales districts it is scentless.

## SARCOCHILUS FITZGERALDII F. Muell., var. AEMULUS, n. var.

Flores punicei cum maculis rubidis numerosis.

Flowers wholly pink or pale crimson with numerous deep red blotches and markings.

This is surely the most attractive variety of a very beautiful species. Typically, the flowers are white with dark crimson blotches at the base of the perianth segments; occasionally they are pure white without any blotches. Var. *aemulus* was collected by me during an excursion with Mr. and Mrs. D. J. Barr of Bellingen, N.S.W., to a mountain gorge near Gleniffer, a few miles north of Bellingen. It was not flowering, and I did not realize its distinctive character until the spring of 1935, when it flowered in my bush-house. During the next few years the plant suffered somewhat from changes of residence, and no flowers appeared again until October, 1943, when two richly-coloured racemes were produced.

## PRASOPHYLLUM FITZGERALDII Rogers &amp; Maiden.

Wallerawang, N.S.W.; Mrs. A. I. Smith, xii.1942 and i.1944. This is a new record for New South Wales, and so far as I am aware the species has not previously been found beyond South Australia. Mrs. Smith sent specimens to the National Herbarium at Sydney about Christmas time, 1942; unfortunately by the time they came into my hands the flowers were quite withered. After softening some out, I concluded that they represented a robust form of *P. gracile* Rogers, although lacking the bidentate tips to the lateral sepals of that species; accordingly they were recorded in "Orchids of New South Wales" (National Herbarium of N.S.W., 1943) under that name. Living plants received from Mrs. Smith in January, 1944, however, proved my first determination wrong, and the species is in my opinion undoubtedly *P. Fitzgeraldii*. This is one of the tall and comparatively robust species of *Prasophyllum*. Typically the flowers are described as prune-coloured, opening from about the middle of the spike first. One of Mrs. Smith's specimens conformed to this description precisely; in the others the flowers were greenish with pink or prune-coloured striations. The history of this species is rather interesting.

It is well known that after the death of R. D. Fitzgerald in 1892, Messrs. Henry Deane and A. J. Stopps (Fitzgerald's lithographer) were requested to continue the publication of the posthumous plates left by him in connection with his classic volumes on Australian orchids. In Vol. ii, Part 5, we have the results of their work, publication then being stopped by the Government of the day. One consequence of this stoppage was that several of the plates were lithographed but never published. Among these is one depicting *Prasophyllum Frenchii* F. Muell. and *Prasophyllum Fitzgeraldii*, the latter being a *nomen nudum*, and no description of it was known. In 1895, Tate published it as a South Australian species, giving Deane as the author of the name (*Trans. Roy. Soc. S. Aust.*, xix, 1895, p. 82). A few years later, Mr. J. H. Maiden sent a copy of the unpublished plate to Dr. R. S. Rogers of Adelaide, who at once recognized *P. Fitzgeraldii* as a South Australian plant known to him, which he had purposed to describe and publish. Tate, however, could give no information in regard to Fitzgerald's connection with it, and Deane disclaimed any personal knowledge of it. He had clearly forgotten certain letters written to him by Baron von Mueller in 1894-5, which are now in the National Herbarium at Sydney, and which will be cited presently. Maiden and Rogers decided to publish the species, under their joint names, as *P. Fitzgeraldii*, and their description and comments will be found in *Trans. Roy. Soc. S. Aust.*, xxxiii, 1909, pp. 202, 212, 216. Mueller's letters to Deane, however, clear up all doubt as to the original sponsor of the name, though technically he may not be termed the author. Under date 8.iii.1894, Mueller writes: "Kindly tell the Hon. Dr. Norton that I believe his view regarding this *Prasophyllum* as new is quite tenable, and to publish it under the name already given by the hon. gentleman." What that name was is made clear in a further letter dated 10.x.1895, in which the Baron expresses his pleasure "that now the Hon. Dr. Norton's *Prasophyllum Fitzgeraldii* is to appear". This was in reference to the next series of plates being edited by Deane and Stopps—which never reached publication. Dr. Norton, a well-known public man of the day, was a great friend of Fitzgerald's, and had given strong support to the publication of "Australian Orchids" under Government auspices.

#### THELYMITRA CARNEA R.Br.

A specimen received from Mr. H. Goldsack, of Coromandel Valley, near Adelaide, is conclusive proof that this species extends to South Australia. For many years there was confusion between *T. carnea* R.Br. and *T. rubra* Fitzg. Ewart and others considered them conspecific. Nicholls cleared up the confusion in *Vict. Nat.*, lvii, 1940, p. 103, showing that Fitzgerald was completely justified in treating them as distinct species, and also that Mueller's *T. Elizabethae* was merely a form of *T. carnea*. The latter, however, was presumed to be restricted to New South Wales and Victoria, *T. rubra* occurring in Victoria, South and Western Australia, and Tasmania. Since then the present writer has recorded *T. rubra* in New South Wales (these PROCEEDINGS, lxviii, 1943, p. 9); and now we have Mr. Goldsack's evidence that *T. carnea* extends much farther west than was supposed. His specimen is thoroughly typical in every respect.

#### CALADENIA CARNEA R.Br.

In "Orchids of New South Wales" (National Herbarium of N.S.W., 1943) the present writer in a note on this species, p. 64, expressed the opinion that the plant figured in Hooker's *Flora Tasmaniae*, ii, 29, t. 125 B, over the name *C. angustata* Lindl., was a form of *C. carnea*. Subsequently, further study of the plate suggested that it represented the closely allied species *C. alpina* Rogers. This conclusion had been reached independently by Mr. W. H. Nicholls, who has collected and handled many specimens of *C. alpina*.

On the same page of the work just referred to, I expressed the view that both the New Zealand species *C. minor* Hook. f. and *C. exigua* Cheeseman should be included in *C. carnea*, and I now definitely propose that they be so included. As is well known to all workers among Australian orchids, *C. carnea* is a species of great variability. I have found it impossible to distinguish Hooker's and Cheeseman's plants from certain forms collected on the mainland of Australia and in Tasmania, and I am of opinion that *C. minor* Hook. f. and *C. carnea* R. Br. var. *pygmaea* Rogers, are identical. If this be

correct, *C. minor* has no specific status, and should be transferred to *C. carnea* under Rogers' variety *pygmaea*. Cheeseman himself appears to have felt some doubt about the status of *C. exigua*, for he first published it as a variety of *C. minor* (*Manual of N.Z. Flora*, 1906, p. 688). It agrees with small forms of *C. carnea* except for the reduction of the marginal calli on the mid-lobe of the labellum to two; and this characteristic has been observed in diminutive flowers of *C. carnea* in Australia. Cheeseman's name may be retained as *C. carnea* var. *exigua*, n. comb.

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## MISCELLANEOUS NOTES ON AUSTRALIAN DIPTERA. X.

DISTRIBUTION, CLASSIFICATION AND THE *TABANUS POSTICUS*-GROUP.

By G. H. HARDY, Queensland University, Brisbane.

(One Text-figure.)

[Read 26th July, 1944.]

## THE DISTRIBUTION OF THE DIPTERA BRACHYCERA.

*Historical.*—When collecting evidence of the remarkable affinity between the Australian and South American Diptera Brachycera, an investigation starting in 1918, the intention was to link this with the hypothesis of “floating continents”, as the idea existed that this might be helpful in establishing the main thesis propounded by Wegener. The subject was pursued through short talks with the late Professor L. Harrison of the University of Sydney, the late C. Hedley of the Australian Museum, and others with knowledge of animal distribution; but with the late E. W. Ferguson the theory was only discussed in its effect upon genus *Tabanus*, part of which showed possible antarctic origin. I attribute below, by names in parentheses, impressions that I had gained by criticism of the antarctic theory of origin received from this generation of former workers, who studied the general problem of animal distribution, but it was not until I had a talk with Mr. H. Longman of the Queensland Museum, that I finally abandoned the above theory in 1922 and turned attention to the view that the whole of the Brachycera may have been derived from a sequence of northern invasions.

To forestall criticism of statements below, it is necessary to point out that *Pelecorhynchus mirabilis* reverts to the *personatus*-group, the two others belong to the *fusciger*-group, as my *fulvus*-group, accepted by Mackerras and Fuller as a colour group, is evidently a complex. Also Hermann records *Apiocera* from North Borneo presumably on a misreading of a handwritten label marked “M'bourne”, several of which I have seen on Victorian specimens of the same species as that identified by Hermann.

*The Antarctic Theory of Origin.*—Mackerras and Fuller (1942) have discussed how the genus *Pelecorhynchus* may have become isolated in the south-east area of continental Australia, the island of Tasmania and Chile. They explain this distribution upon the theory of “antarctic” origin, that is to say, the genera so distributed evolved in the southern hemisphere at the time when it was theoretically possible for them to have had a wide dispersal in the temperate climate of southern land connections, the Gondwana Land, since disrupted.

Quite apart from the difficulty of fixing the geographical location as a source or origin for any winged animal type (Hedley) is the major difficulty of accepting the antarctic hypothesis due to the time limits (Harrison). This difficulty lies in the idea that *Pelecorhynchus* and similarly distributed genera are all highly evolved along their respective lines and yet each must represent a faunal element existing anything up to one hundred million years back to its genesis, developing and maintaining so close an affinity in Australia and Chile as to have the Chilean forms placed in Australian groups after, say, forty million years' isolation. The epochs in time estimates are given by A. L. du Toit in *Our Wandering Continents* (1937, p. 48), and allowance has been made for the breaking up of the continental mass depicted there for Eocene times (p. 18). Expressed in these figures, the objection is more easily comprehended, and also it will be noted that only the more advanced of the two Australian groups comprising *Pelecorhynchus* is retained in Chile, whereas the more primitive one is almost exclusively represented in the Tasmanian fauna, a feature that fits best the opposed theory. Moreover, if Philip be justified in placing the genus *Bequaertomyia* in the *Pelecorhynchinae*, then much of the argument for the antarctic theory of origin must collapse.

*The Theory of the Northern Invasion.*—For the purpose of orientating the whole outlook, one can assume that every major group of the Brachycera, at least down as far as subfamilies and even tribes, had its origin in tropical and subtropical climates. This may be substantiated on the idea that only in such places does one find the optimum breeding rate and the greater competition for survival amid an abundant competitive fauna. The evolution rate would thus be enhanced compared with that under conditions in more temperate zones. In accord with this, there occurred also the gradual displacement of the original type in the tropical region by later evolved types, the primitive ones surviving best in the least accessible places to where they had penetrated. Moreover, this gives a radiation polewards in diminishing proportion of species and genera, with a trend towards preserving a higher proportion of primitive characters in regions most remote from the place of origin. Australia, being comparatively isolated, may afford a better refuge for survival of primitive characters than most continents (Longman).

If the idea be well founded, then one would expect to see parallel evidence of the same poleward dispersal with recent genera permeating all regions, dominant in the tropics and reduced in the outer ones where a trend towards retaining primitive structures on such recent genera would also be noted.

This condition is apparent in *Sarcophaga sensu stricto* (Hardy, 1943), a genus undoubtedly splitting into three recognizable subgeneric units between Australia and India. The subgenus *Chrysosarcophaga* seems to be limited in range from India to Australia, petering out with one species in Tasmania which is also found around Mt. Kosciusko in New South Wales. The subgenus *Parasarcophaga* is abundant in the Holarctic and Ethiopian regions, reaches Australia, and the one species in Tasmania is dominant over the southern half of the mainland. Each of these Tasmanian species has the aedeagus slightly out of harmony with those of the more tropically-situated allies, being not so highly developed. The typical subgenus *Sarcophaga* is limited to the small *carinata*-group in the Palaearctic region and the larger *crinata*-group which ranges from India to Queensland. Of the three subgenera, *Chrysosarcophaga* appears to preserve best the more primitive general characters and so supports the theory.

The Lower Brachycera show a similar feature, as for instance in the Stratiomyiidae, the Pachygasterinae, a subfamily considered by James (1936) to be the most advanced one, has dominance in tropical regions and is reduced to four species in two genera within Tasmania; but structural details are not fully understood. On the other hand, the genus *Odontomyia* represents a much older type and is showing a far advanced trend towards elimination from tropical and subtropical areas. It is abundant in northern and southern temperate zones, and only one species is found in northern Australia, the majority, seven of the ten known Australian species, occurring in Tasmania.

A distribution still more reduced is seen with Apioceratae. The genus *Apiocera* is known from southernmost Africa, the Australian mainland and Chile, whilst outside this Gondwana distribution, it is found only in the Rocky Mountain area north of Mexico to the Canadian border. The remaining three genera of the family are similarly distributed, one each occurring in three of these areas, Africa alone being excepted.

Ceratomerinae is a subfamily of Empididae restricted to Australia, New Zealand and Chile, whilst *Pelecorhynchus* is confined to the first and last of these.

Here, then, is seen a sequence of diminishing areas of dispersal, a dwindling in habitat that may be reflected throughout the Brachycera and that logically leads to endemic forms like *Exeretoneura* (Nemestrinidae) that become limited to south-eastern Australia and even to Tasmania only, and there are many other types of Brachycera that similarly support the theory of poleward dispersal. This general diminishing area of dispersal may also bear upon the relative age of the types discussed, but there is no evidence to show in which epochs they were respectively dominant.

*Conclusion.*—The general view that may be gathered from these remarks, suggests that in whatever way the isolation of *Pelecorhynchus* in two areas of the southern hemisphere was brought about, the antarctic theory is likely to prove unsatisfactory, and if adopted, it is difficult to see the line along which the investigation will proceed. The opposed theory has the advantage, at present, in that it not only avoids building a theory upon a theory, but also opens the way to a comprehensive search for data.

## SUPERFAMILIES OF DIPTERA.

During the hundred years from Latreille (1825) to Tillyard (1926), several authors have arranged this order under groups higher than families, and of these Coquillett (1891) introduced the first simplified system based upon the modern conception of superfamilies.

The practical difficulty experienced hitherto in accepting superfamilies lies in the fact that no characters on the adult were found to define their limits adequately. Malloch (1917) returned to the method of classifying on larval and pupal characters, which system was initiated by Brauer (1864), but succeeded in making little alteration to Brauer's plan in that very inconvenient way of arranging superfamilies, and no author subsequently has made use of the scheme. The attempt made by Tillyard, with the aid of the late A. L. Tonnoir, certainly improved upon the general scheme, bringing adult characters to bear upon superfamilies, but there, too, the result is universally regarded as unsatisfactory. The fresh effort made here, is based upon terminal characters of the male, and thus introduces a new set of characters for building up a stable classification.

Coquillett proposed using eight superfamilies under Latreille's two suborders, and Malloch increased this to twelve in the Orthorrhapha alone, making fifteen in all if those of the Cyclorrhapha be added. Tillyard reduced the number to twelve, but in the present paper only nine are regarded as valid, or if future adaptations are to be made in the Nematocera and Hippoboscoidea, this number still may be high.

*Sections.*—At present I can see no characters of sufficient importance upon which to use the grade "suborder" and make it worthy of comparison with those of other orders. Latreille proposed two primary sections, the Proboscidea and Eproboscidea, the latter being limited to one family, Pupipara (now Hippoboscoidea), and Walker (1848) raised these to suborders. Following upon ideas expressed by Osten-Sacken, Williston accepted three suborders in accord with (*a*) Nematocera, (*b*) the rest of the Orthorrhapha, and (*c*) the Cyclorrhapha, the two last names being the suborders of Brauer's scheme. To these White (1914) added a fourth suborder, Pupipara. Tillyard reduced this number to two once more, adopting Macquart's two primary divisions, Nematocera and Brachycera, and he restricted the name Orthorrhapha in both scope and status, regarding it as being a division of the suborder Brachycera. In this, Tillyard relied upon the view that evidence showed that the original dichotomy, though not yet complete, was undoubtedly into Nematocera and Brachycera. Williston pointed out that the soundest primary division was that proposed by Brauer, in so far as it contrasted by characters of the larva and pupa, to which may be added here the male terminalia, too.

*Subsections.*—It is advisable, as a temporary measure, to join superfamilies together under subsections so as to incorporate the name Nematocera. Other subsections of equal importance have names applied by early authors who conceived them to be major units. When the superfamily status within the Nematocera becomes understood, these subsection names will no longer be needed and will disappear from the classification.

Nematocera, based on Latreille's Nematocera, is used by all authors and only Lameere (1906) proposed modifying its scope. Brachycera was used by Macquart to cover the remainder of the order, but Schiner (1864) and some later authors use it in a restricted sense. It stands as a comprehensive group unsuited for a subsection. Macquart proposed Entomocera to cover the major part of the Tabanoidea, and Aplocera to cover the remainder of the Brachycera. Although Tanystoma originally covered part of the Tabanoidea, Latreille finally restricted its scope under Notacantha, Tabanidea and Tanystoma where it became available for the Asiloidea. Macquart used the name in this sense, but Brauer and Malloch needlessly transferred the name to the Tabanoidea which had been eliminated from its scope.

Aschiza Brauer covers Syrphoidea as a subsection, remarked upon by Macquart but left unnamed by him, whilst his Dichaeta covers the same scope as does the later Schizophora Brauer. Macquart's divisions Calyprtrata and Acalyprtrata\* arise from

\* In his *Diptères Exotiques*, Macquart used Calypterata and Acalyptera, the latter being an obvious error. I know not who amended this by omitting the "e", and there are other variations used, such as Calypterae and Acalypterae.

Calypteratae Desvoidy which, in the original sense, contained at least parts of the families Oestridae, Muscidae, Calliphoridae (including Sarcophaginae), Tachinidae and Conopidae, but excluded Phaoniinae, Anthomyiinae, etc. Macquart amended this faulty conception but excluded the Oestridae, an error subsequently rectified. The name Calyptrata now covers a slightly wider division than does the earlier Creophiles Latreille that has been allowed to lapse.

Myodaires was used by Desvoidy with no definite conception in the classificatory sense, but was convenient as a substitute for *Musca sensu lato*, when *Musca* had become very restricted. The modified name Myodaria, as far as I have traced, was first used by Lameere to balance Syrpharia (now Syrphoidea), whilst Williston used it to balance Pupipara, and in both cases it remains identical with Dichaeta.

*Superfamilies.*—On terminal structures of the male, the Brachycera fall into four divisions. Those of the Tabanoidea are like those of the Nematocera, the primitive claspers being hinged to swing horizontally towards each other. Claspers on the Asiloidea swing vertically, parallel with each other, or become fused at their bases with the apex pointing upwards. The terminal segments of the Syrphoidea take a semi-circular bend to the right, and when at rest, the aedeagus is protected in a phallic pouch formed in the pleural region about the sixth segment. There are no claspers here, but secondary claspers appear in the fourth division where the phallic pouch forms part of a large completely enclosed genital cavity. There are no intermediate forms known between these four divisions, each having its distinctive and clear-cut type of male terminalia.

Coquillett proposed seven superfamily names, of which six still stand: Tipuloidea, Bibionoidea, Tabanoidea, Asiloidea, Syrphoidea and Muscoidea. In the Nematocera, Malloch added four more, two surviving: Cecidomyioidea and Culicoidea. Tillyard remodelled this on the basis of six superfamilies, but only the four mentioned are retained.

Under the Brachycera Orthorrhapha, Malloch used six superfamilies, reduced to three by Tillyard, but only two by Coquillett are accepted here: Tabanoidea and Asiloidea. Throughout literature, under Cyclorrhapha, three superfamilies are accepted, proposed by Coquillett who, however, did not designate a name for the Hippoboscoidea. The resulting classification now stands as follows:

Order. Section. Subsection. Superfamily.	DIPTERA. Orthorrhapha. Nematocera. Tipuloidea. Culicoidea. Cecidomyioidea. Bibionoidea.	
Subsection. Superfamily.	Entomocera. Tabanoidea.	} Brachycera
Subsection. Superfamily.	Tanystoma. Asiloidea.	
Section. Subsection. Superfamily.	Cyclorrhapha. Aschiza. Syrphoidea.	
Subsection. Superfamily. Division.	Dichaeta. Muscoidea. Acalyptrata. Calyptrata.	
Superfamily.	Hippoboscoidea.	

In a criticism of my original draft on the classification of Diptera, Dr. C. P. Alexander states that: "In whatever superfamily the Psychodidae are placed, the Tanyderidae must be placed in the same", and he thinks there would be no objection in adding the Psychodidae to the Tipuloidea. Also I note that it may be necessary to amalgamate the Culicidae with the Tipuloidea in the event of a further reduction in the number of acceptable superfamilies, and judging from structures that I have been able to find in the Bibionoidea, this superfamily may include characters on the male terminalia that are more primitive than any I have seen in the Tipuloidea so far studied. Because of its approach to the Brachycera, there is a tendency to regard the Bibionoidea as advanced in respect to the Tipuloidea, whereas the true position may be found when the terminalia are intensively studied. Probably the Tipuloidea represent a side issue derived from a low position in the sequence of development towards the Brachycera, and the Bibionoidea lie nearer to the direct sequence.

In listing nine major trends in the evolution of flies, Williston pointed out that "all or nearly all . . . are polyphylectic, resulting in numerous cases of parallel resemblance which must be taken into account in any attempt at a true classification". This applies also to the terminal characters, but everywhere occasional characters are added and widely repeated over the order, and any failure in recognizing their status may bring divergent views on the evolutionary sequence at least. It becomes difficult, therefore, to assess the phylogenetic relationships between superfamilies, but the four under Nematocera are in accord with the divisions apparently seen by the late F. W. Edwards, and it is expedient that I should accept this and place it upon a superfamily basis awaiting further information. Some slight amendments may be needed in the Brachycera, but the main work seems to have been covered there.

Jobling (1936), writing on Streblidae, regards this family as belonging to the Acalyptrata, and the family Hippoboscidae is said to have its affinities with the Calyptrata, thus making the Hippoboscoidea a complex, but it is convenient to retain the superfamily until the affinities can be assured.

*Key to Superfamilies of the Diptera.*

1. Male terminalia of primitive rectilinear form, or else curvilinear with the eighth and ninth tergites adjacent to each other. Coxopodites are present . . . . . ORTHORRHAPHA . . . . 2  
 Male terminalia either curvilinear combined with an inverted hypopygium, so that the ninth tergite is adjacent to the eighth sternite, or else completely circumverted. The aedeagus is always directed anteriorly, lying within a phallic pouch formed normally within the fifth and sixth abdominal segments. Coxopodites always absent. . . . . CYCLORRHAPHA . . . . 7
2. With claspers hinged to swing towards each other within 45 degrees of the horizontal plane, and attached to laterally placed supports (basistylus of taxonomists). Terminalia of varied forms, but never curvilinear and the aedeagus is always directed rearwards . . . . 3  
 With claspers hinged to swing in the vertical plane, or fused with the apex directed upwards. Terminalia of varied forms, including the simple curvilinear type in which the aedeagus is often directed forwards, but never lies within a phallic pouch. . . . . ASILOIDEA
3. With pulvilliform empodium. Palpi never more than two-segmented and rarely do the antennae have more than three or four articulating segments . . . . . TABANOIDEA  
 Without pulvilliform empodium. Palpi normally with four to six segments and the antennae usually with many articulating segments . . . . . 4
4. With the median cell present, or if absent then two anal veins are complete. Failing this (Psychodidae) the body and wings are densely hairy, and normally the wings are held roof-like over the abdomen . . . . . TIPULOIDEA  
 Without the median cell and never more than one anal vein is present. Never densely hairy on wings, but if dense scales occur, these are limited to the veins . . . . . 5
5. Due to the folding of wings during pupal development, the adult may have a network of, or fan-shaped, creases. When these are not present, the wings are broad and at least have a distinct anal lobe and well-developed venation. If the radial field be reduced below four branches, then the median field has at least three branches. In Scatopsidae the veins may be very weak and overlooked, but the broad form of the antennae (typical Bibionid type) relegates the species to this superfamily . . . . . BIBIONOIDEA  
 Wings never with such creases and the anal lobe is not developed, or if slightly so, then the venation is much reduced. Antennae always slender . . . . . 6
6. Ocelli never present and usually the venation is fairly complete, the radial vein being four-branched, or if less than four branches occur in the median field. At the maximum reduction (Chironomidae which has less than 16 segments in the antennae) at least one vein occurs in the median field. Proboscis often formed for blood-sucking . . . . . CULICOIDEA

- Ocelli present (Mycetophilidae) or absent (Cecidomyiidae). In the latter case the veins of the median field are entirely absent. Subdivisions of antennal segments increase their number to about 30 normally, and may become excessive; never less than ten segments are present . . . . . CECIDOMYIOIDEA
7. With the upper lamella retained as a pair of swollen tubercles lying one each side of the anus thus: (O), the "O" representing the papilla and the parentheses representing the divided lamella. The armature of the aedeagus is normally large and complex and no secondary claspers are developed. The primitive phallic pouch is usually placed latero-ventrally . . . . . SYRPHOIDEA
- With lamella eliminated. Terminalia always circumverted with the genital cavity opening ventrally, the concealed genital pouch forming part of the cavity. Armature of the aedeagus very restricted or absent. One or two secondary claspers frequently developed . . . . . 8
8. Normal flies with coxae nearly always placed close together. Abdominal sclerites nearly always clearly defined and separated, but occasionally some may fuse together. Parts of the male terminalia usually all present . . . . . MUSCOIDEA
- Abnormal flies with coxae spaced widely apart and usually most or all abdominal segments are fused together. Parts of the male terminalia are vestigial or eliminated. Flies parasitic on vertebrates . . . . . HIPPOBOSCOIDEA

*Evolution of claspers.*—As authors mostly assume all types of claspers to be homologues, an idea not now tenable, an explanation must be given for their treatment in the above key. Snodgrass, in his *Principles of Insect Morphology*, 1935, uses the terms *coxopodite* and *harpago* for parts that Tillyard calls the *lateral gonapophyses*, whilst the terms gonapophyses is restricted by Snodgrass to a structure that does not occur on Diptera. If the coxopodite and harpago truly represent a limb then, in the primitive form, both must have had a vestiture. In Simuliidae such a vestiture is found equal in density on each part and also the harpago may have some of the hairs thickened to bristles, their number varying with the species. Bristly hairs are found also on the harpago of Tipuloidea and Culicoidea where other vestiture is absent. Vestiture entirely disappears in higher families of Nematocera and is unknown to me in Tabanoidea and Bombyliidae. On other Asiloidea the remnant of vestiture occurs on *Apiocera* in the form of bristly hairs on the claspers, and here, as elsewhere (Bombyliidae excepted), a very significant change already has taken place within the superfamily, namely, lower forceps developed forming a partly enclosed genital cavity.

The lower forceps arise as an extension of coxopodites and bear the same vestiture. Attached to the inside is a pair of claspers which, apparently, are not homologous with the harpagones (primary claspers). Probably they are part of the forceps curved inwards, differentiated by a cleft along the line of curvature, remaining somewhat generalized with bristly hairs on some species of *Apiocera*, and becoming clasper-form both with and without bristly hairs on others; the harpagones quite disappear.

The coxopodites, harpagones and lower forceps do not form on Cyclorrhapha, where yet another change is traceable through the now well-known alteration that takes place with the sclerites. The apical or ninth segment (hypopygium) becomes inverted and, from the sixth onwards, the segments take a spiral formation that brings the ninth segment to the erect position once more, the circumversion of the hypopygium being thus completed. In addition, the whole of the modified segments concerned take a curve to the right, bringing the aedeagus into a phallic pouch situated in the pleura, as seen in Syrphoidea where no claspers occur, and instead, an armature developed at the base of the aedeagus and in continuity with it.

Under this new condition the sixth and ninth sternites and the seventh and eighth tergites are on the inner curve, and they become reduced or eliminated in conformity with the amount of development that has taken place. In Calyptata, where the development is moderately advanced, the aedeagus has moved forwards, dividing the remnant of the ninth sternite, and again still further forwards, dividing the remnant of the eighth tergite, too. Thus arises a pair of remnants each side of the aedeagus in Muscoidea and these are called claspers.

Snodgrass refers to these as a pair of free lobes arising from the ninth sternite, thus indicating their position but not their origin, and moreover, he has assumed the sixth segment is eliminated in order to justify his method of numbering sclerites.

Other authors have disputed whether it be the sixth, seventh or eighth segment that is missing, but I find that, with my own interpretation, it is quite unnecessary to assume the loss of a segment, for which reason I think the present account of origins is likely to prove satisfactory.

#### Superfamily TABANOIDEA.

In this superfamily five main stems have been traced, and of these, the Stratiomyiid-stem has developed not only a specialized venation, but also shows a very varied abdominal shape with the flattened or depressed type prevailing, reaching the disc form as in Pachygasterinae. The Cyrtid- and Nemestrinid-stems also have a specialized venation, the former again showing a variety of abdominal shapes. The Tabanid-stem has the abdomen depressed, reaching oval-depressed, but one form known to me is short cylindrical, and the South American genus *Acanthocera* has some species with clubbed abdomens.

The Tabanid-stem, with normal venation, arises from the Leptid-stem, which is regarded by universal consent as being the more primitive, and shows a tapering cylindrical abdomen together with the advanced sphero-conical form as on *Dasyomma*. When arranged in phyletic sequence showing the varied stages reached from cylindrical to sphero-conical shaped abdomen, it is noted that this change is mainly associated with an increase in capacity relative to surface area, and so the trend towards the depressed form might be associated with maintaining a more consistent relationship between capacity and area of surface, a phenomenon bearing, presumably, upon development in egg capacity and physiological changes connected therewith.

This is more readily seen in Asiloidea as the number of eggs estimated for Asilidae with cylindrical abdomens is 100 or less as against 300 and 400 for other more advanced shapes, but the present information is rather scanty. The capacity of blowflies with sphero-conical abdomens is found to be 2,000 eggs and of members of the genus *Oncodes* (Cyrtidae), which have very distended abdomens for their size, is many thousand minute eggs.

As no suitable key has yet been given to cover the Australian Tabanidae, the following one to subfamilies may prove of use. A few difficulties need to be overcome before a key to genera is formed.

#### Family TABANIDAE.

##### Key to Subfamilies of the Tabanidae.

1. Abdomen nearly sphero-conical or somewhat approximating to that form. There are four or five normal segments visible, the sixth and remainder being highly reduced, tubular and incorporated with the genital segments. Hind tibiae with spurs . . . *Pelecorhynchinae*  
Abdomen with seven normal segments visible . . . . . 2
2. Hind tibiae with spurs . . . . . *Pangoninae*  
Hind tibiae without spurs . . . . . *Tabaninae*

Recently Mackerras and Fuller (1942) proposed raising the *Pelecorhynchinae* to family status on larval characters, and they discuss the position regarding the adult characters. The authors, however, fall to the usual error of regarding as primitive some characters not yet proved to be so, and they make their remarks with this bias. There are now twelve or more family names proposed, arising from studies on Tabanoidea, seven being monotypical or nearly so, and the movement to add to their number has not yet ceased.

#### Subfamily PELECORHYNCHINAE.

Modern researches on terminalia do not bear out the statements that "The ovipositor of the female is, however, much more primitive than that of any Tabanid" and "the shovel-shaped eighth sternite with its cleft distal end, which, from its resemblance to the corresponding sternite of *Chorista*, . . . represent the most primitive condition found in Diptera" (Mackerras and Fuller, 1942, p. 28). Indeed, associated with these female terminalia, nothing is shown to be fundamentally primitive, but instead the data indicate a more highly advanced type than generally supposed. The reduced tenth tergite, the loss of the suranal plate (if it be not confused with the apparent two-segmented cerci), the lost ninth sternite (if perchance it be not combined with the

elongate eighth), enhance the idea of the ovipositor being an advanced type. Probably Mackerras and Fuller also err in their interpretation of that difficult feature, the male terminalia, in so far as they use the term "cerci", the presence of which is disputed on any male dipteron. In some cases the apparent cerci are remnants of the suranal plate, the eleventh tergite of some authors.

#### Genus PELECORHYNCHUS Macq.

Mackerras & Fuller, 1942, 45.—*Archeomyia* Philip, 1941, p. 3, genotype, *P. fulvus* Ric.

This synonym is not given by Mackerras and Fuller, who were unaware also that Philip suggests the genus *Bequaertomyia* Brennan, based on a rare and more primitive species on the Pacific Coast of the United States, also belongs to the Pelecorhynchinae. *Archeomyia* is erected on the one character only, namely, the frons on the male being as broad as long and two-thirds as broad on *P. mirabilis*, but as the eyes are approximate on *P. distinctus*, the proposed genus does not conform to the *fulvus*-group. The comparative width of the frons does not seem a reliable character for generic erection on any of the Australian Brachycera.

#### Subfamily TABANINAE.

##### Genus TABANUS.

Of the four sections into which this genus is divided, there are now 16 species, as shown below in the first, 37 in the second, and 2 in the fourth, leaving about 70 species for future consideration, nearly all of them belonging to the third section.

#### Section 1.

##### *Tabanus posticus*-group.

*T. avidus*-group, Hardy, Proc. Linn. Soc. N.S.W., lxiv, 1939, 42.

Distinguished by the frons being 5 and 6 times longer than broad. So far this is the only group brought under the section, and the distribution of the species suggests that some of them may be subspecific in value or even less. Natural units may be observed by grouping in the list below, the first and second, the third to sixth, the seventh to ninth, the eleventh to thirteenth, and the fifteenth and sixteenth.

##### Key to Species of the *T. posticus*-group.

- |   |                                 |
|---|---------------------------------|
| 1. Callus long, reaching well beyond the middle of frons .....              | 2                               |
| Callus reaching to about, or before, middle of frons .....                  | 6                               |
| 2. Antennae yellowish-brown .....   | 3                               |
| Antennae black .....  | 4                               |
| 3. Upper section of callus linear .....                                     | <i>torressi</i>                 |
| Upper section of callus tapering .....                                      | <i>palmensis</i>                |
| 4. Whitish hair-spots on median line of abdomen large and distinct .....    | 5                               |
| Whitish hair-spots on median line of abdomen small and weak or absent ..... | <i>wentworthi, laticallosus</i> |
| 5. Upper section of callus linear .....                                     | <i>magneticus</i>               |
| Upper section of callus tapering .....                                      | <i>doddi, alternatus</i>        |
| 6. Antennae black or mainly so .....  | <i>heroni, victoriensis</i>     |
| Antennae lighter, red or at least yellow at base .....                      | 7                               |
| 7. Appendix present in venation .....                                       | 8                               |
| Appendix absent .....   | 9                               |
| 8. Legs black and brown .....   | <i>nigritarsis</i>              |
| Legs yellowish .....  | <i>ochraceoflavus</i>           |
| 9. Dark species. Legs black or brown, only tibiae yellowish .....           | <i>duplonotatus, davidsoni</i>  |
| Yellow or yellow-brown species. Normally with yellow legs .....             | 10                              |
| 10. Small species up to 9 mm. Femora and tibiae may be dusky .....          | <i>brevior</i>                  |
| Larger species above 12 mm. Legs always light coloured .....                | <i>posticus, sanguinarius</i>   |

*T. torressi* Ferg. & Hill 1922. ♀.—Islands of the Torres Strait.

*T. palmensis* Ferg. & Hill 1922. ♀.—Queensland; Palm Island.

*T. doddi* Taylor 1916 (*abstersus* Taylor 1913 in part, *nec* Walker), (*macquarti* Ricardo in part). ♀.—North Queensland.

*T. alternatus* Ferg. & Hill 1922 (*limbatinervis* Macquart 1849, *preocc.* Macq. 1847), (*macquarti* Ricardo 1915, *preocc.*), (*abstersus* Taylor in part). ♀.—South Queens-

- land and New South Wales. According to Taylor, South Australia as well, but this needs confirmation.
- T. alternatus* var. *magneticus* Ferg. & Hill 1922. ♀.—Queensland; Magnetic Island.
- T. wentworthi* Ferg. & Hill 1922. ♂, ♀.—New South Wales; Blue Mountains.
- T. laticallosus* Ricardo 1914, *nec* Taylor (*rufoabdominalis* Taylor 1917). ♂, ♀.—South Queensland; Moreton and Stradbroke Islands. New South Wales; Byron Bay.
- T. heroni* Ferguson 1921. ♀.—New South Wales; Dorrigo. Ferguson & Hill place this as a variety of *laticallosus* and hardly separable from *victoriensis*.
- T. victoriensis* Ricardo 1915. ♀.—New South Wales and Victoria.
- T. duplonotatus* Ricardo 1914 (*parviccallosus* Taylor 1917, *nec* Ricardo). ♀.—South Queensland.
- T. nigratarsis* Taylor 1913. ♀.—North Queensland and Northern Territory.
- T. davidsoni* Taylor 1919. ♀.—South Queensland and New South Wales. The record by Ferguson and Hill of a specimen from north Queensland needs confirmation.
- T. ochropterus* Ferguson & Henry 1919. ♀.—New South Wales; Camden Haven district.
- T. brevior* Walker 1848, *nec* Taylor 1919 (*marginatus* var. B Walker), (*anelosus* Summers 1912), (*australis* Taylor 1916), (*crypserythrus* Taylor 1919). ♂, ♀.—Northern Territory.
- T. posticus* Wiedemann 1828 (*Atylotus avidus* Bigot (1892), (*fuscipes* Taylor, 1913, *nec* Ricardo), (*taylori* Austen 1914). ♂, ♀.—Queensland and New South Wales. Ricardo suggested the identity of Wiedemann's species, but did not use the name. There can be little doubt that the synonymy is correct.
- T. sanguinarius* Bigot 1892 (*Atylotus*), (*nigropicta* Froggatt 1915, *nec* Macquart). ♀.—South Queensland, New South Wales and South Australia.

#### Superfamily ASILOIDEA.

A row of articulating spines is peculiar to this superfamily, each spine articulating in a membraneous ring on the apparent ninth tergite of the female. Centered around this structure have been many comments made usually on the idea that the character is recent in origin and isolated. Investigations show that it must have arisen early in the evolution of the Asiloidea as it becomes vestigial and disappears in the higher forms, but remains almost invariably present in the more primitive ones; *Phellus* is an exception.

This and other characters discussed in the prior notes (Hardy, 1942), when placed on a phylogenetic basis, brings the order of the families almost into alignment with that adopted by earlier authors and the subject may be summarized as follows:

*Bombyliidae*. There is but one plate, possibly the ninth and tenth tergites combined, bearing these articulating spines which are numerous and closely set together. They are consistent almost throughout the family.

*Mydidae* and *Apioceratidae*. The spines are fewer and more widely spaced, whilst along the median line of the tergite lies a ridge. This is on the apparent ninth tergite and no variations are known to me.

*Asilidae*. The ridge lying along the median line is detached in this family wherever found, and the spines are still present in the same form, but now lying on a pair of acanthophorites, one each side of the ridge. In the more advanced genera the ridge disappears, leaving the acanthophorites still divided, and these later become vestigial and disappear in advanced genera.

*Therevidae*. No ridge is present and the acanthophorites remain consistently paired and well formed; rarely if ever reduced beyond this.

*Scenopinidae*. Apparently the character has been lost throughout this family.

*Empididae* and *Dolichopodidae* are normally without the structure, but it becomes highly modified in the more primitive forms of the latter at least.

This order follows closely that proposed by Brauer in 1883, the difference being that the Bombyliidae are placed by him between Asilidae and Therevidae, so I believe the arrangement will be found satisfactory. Coquillett proposed making Apioceratidae, Mydidae and Bombyliidae, in this reversed sequence, into a separate superfamily, and the sequence of the first three names listed by him under Asiloidea is similarly reversed.

The primitive Asiloidean female terminalia given here (Fig. 1) is a composite figure showing a set of parts as would be seen from the latero-ventral aspect, with the pleural membrane of the eighth segment torn away to exhibit the gonopore lying within the genital groove bordered by a sclerite that represents, presumably, the ninth sternite which normally is hidden within the genital cavity. Many Asilidae have only the cerci missing, and they vary towards having most parts missing in the advanced forms, whilst

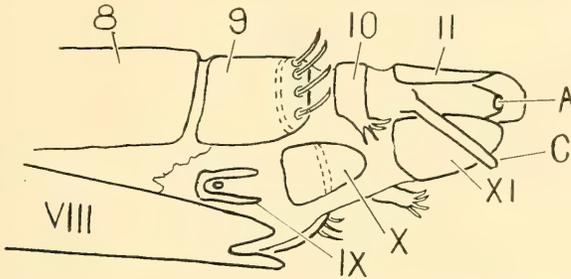


Fig. 1.—A composite figure of sclerites found on female terminalia of primitive genera of Asiloidea.

8, 9, 10, 11, the eighth to eleventh tergites respectively. A, the anal papilla. C, the cercus. viii, ix, x, xi, the eighth to eleventh sternites respectively.

The *acanthophorites* are represented by sclerite 9 which becomes divided along the median dorsal line. The *supplementary spines* occur on 10. The *suranal plate* if divided becomes the *dorsal lamellae* and is 11. The *ventral lamella* is xi. The *median plate* is x. The *chitin bordering the genital groove* is ix. The *genital cavity* is formed by x, ix, the apical part of viii, together with the membrane joining them. The *dorsal ridge*, not shown in the figure, is limited in length to the median line of the apparent ninth tergite, and may be in continuity with the *acanthophorites* or separated from them. When the upper lamellae are formed, they may be mistaken for cerci, if true cerci be absent. Cerci, however, are always distinctly separated from each other and the lamellae always adjacent to each other, as far as yet found. Invariably the so-called cerci on the males are the upper lamellae throughout the Asiloidea.

in the process of reduction, sclerites may become divided, or their shapes altered, or only minute remnants are retained. There are, however, gaps between some families, noticed in the sequence so far traced, and morphologically the structures are not certainly understood.

In the modern method of counting, the eighth tergite is normal, the ninth apparently has a row of articulating spines at the apex, but as this might be a complex of the ninth and part of the tenth segments, this sclerite is divided by a double dotted line. The apparent tenth tergite bears the supplementary spines arising from a flange forming an extension to this sclerite. The upper lamella forms the eleventh tergite covering the anal papilla from above, and in the primitive form it is a single sclerite (suranal plate); usually it is divided longitudinally and may disappear on Dolichopodidae where the cerci are retained in the form shown on the figure, namely, long and cylindrical. The ventral lamella becomes the eleventh sternite by this count, and may become weakened and disappear. The tenth sternite, in the primitive form, seems to be divided transversely as on Apioceratidae, but two trends are noted arising from this, one in which each half plate is divided longitudinally making four parts in all, as on *Bathypogon* and *Stenopogon*, the other in which the posterior half disappears and only an anterior pair of pieces remains; all, however, may disappear. The genital groove in which the gonopore lies, may have one, two or three ridges of chitin bordering it, but in the primitive form the ridge is found in one piece and U-shaped, forming the ninth sternite. The eighth sternite is normal with the usual cleft at its apex.

This interpretation is based upon the view that the abdomen is eleven-segmented, and if the figure be interpreted on a ten-segment or a twelve-segment basis, then it would be necessary to presume new structures arose in the former case, and in the latter the cerci are either misplaced or are needing some other origin to explain them. Mackerras and Fuller (1942) have given drawings for some terminalia of female Tabanoidea and

these are in alignment with the present interpretation. Other authors available to me find, apparently, only nine segments and the proctiger which is left unnumbered. Snodgrass (1935) uses only the Cyclorrhapha and Tipulidae in his interpretation, but his Panorpid figure agrees with the present numbering, his eleventh segment being the proctiger with two-segmented cerci. It is not certain if this method of numbering be correct.

#### Acknowledgements.

I have to thank Dr. C. P. Alexander for criticisms of my first draft on classifications of Diptera compiled from all authors available, and of which the above summary forms an amended abridgement; and also Colonel Cornelius B. Philip for drawing my attention to a paper which discusses the Pelecorhynchinae and which was not included in the studies by Mackerras and Fuller. I would also draw attention to Dr. G. C. Crampton's discussion on Phylogeny in the *Guide to the Insects of Connecticut*, Part iv (Diptera), 1942, pp. 115-8, where tentative suggestions are made concerning lines of descent. Here the conception of superfamilies is quite at variance with mine, making three superfamilies out of my conception of Tabanoidea, and three more under Asiloidea, one being Bombyloidea, including Nemestrinidae, Bombyliidae and Cyrtidae. This paper follows current ideas, bringing together some admittedly doubtful relationships, and was not taken into account in the above discussion, being too recent and apparently subject to wide alterations in the near future.

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## A MODIFIED RESPIROMETER FOR STUDIES ON THE RESPIRATORY QUOTIENT OF APPLES.

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(From the Department of Botany, University of Sydney.)

(One Text-figure.)

[Read 26th July, 1944.]

In previous studies in the metabolism of apples by Trout *et al.* (1942) and Hackney (1943*a*, 1943*b*) no values for the respiratory quotient were obtained. Such values were thought to be desirable in order to indicate the type of respiration being carried on.

Methods such as those of Magness and Diehl (1924), Haller and Rose (1932) and Platenius (1942) have been used to measure the respiratory quotient of batches of more than one fruit. Besides being unsuitable for work on individual fruits these methods have the disadvantage that they usually require several days for a single reading.

The method described by the present writer has been used satisfactorily to measure the respiratory quotients of individual apples. Usually the time required for one reading has been not more than three hours.

The apparatus is shown in Fig. 1. It is essentially a differential volumeter of the type used by Fenn (1935) and modified by Duryee (1936), Thimann and Commoner (1940) and Tyler and Berg (1941).

Each of the vessels, A, B, consists of two thick-walled hemispheres with flat-ground glass flanges which can be quickly separated or sealed together with petroleum jelly. Vessel A is the respiration chamber in which the fruit is put; vessel B is the compensating chamber. The capacity of each vessel is about 500 ml.

The vessels are connected to each other by means of the graduated capillary tube, C<sub>1</sub>, which contains a small index drop of kerosene, coloured with Sudan III. By means of 3-way stopcocks, D<sub>1</sub> and D<sub>2</sub>, the atmospheres of the two vessels can be brought into contact with the index drop.

The long graduated capillary tube, C<sub>2</sub>, contains a column of mercury the level of which is adjusted by means of a screw-clip, E, compressing the rubber tubing at the end of the capillary. The bore of the capillary tubing is about 0.8 mm. and is coarse enough to allow free movement of the index drop. The small graduations on tube C<sub>2</sub> are about 1 mm. apart. Each division is equivalent to a volume of 0.00213 ml. The full length of the scale is equivalent to 0.526 ml.

The two vessels are immersed in water which is vigorously agitated by the mechanical stirrer, S, set directly between them. The whole apparatus is kept in a room maintained at constant temperature.

To determine the respiratory quotient (R.Q.) of the fruit, it is necessary to measure the rates of uptake of oxygen and output of carbon dioxide. In order to measure the rate of uptake of oxygen an absorbent for carbon dioxide is introduced into the respiration chamber. Granular soda-lime was found to be most suitable. In preliminary experiments, N/10 barium hydroxide was introduced through the bottom of the sphere, as shown in Fig. 1A. It was found that the efficiency of absorption was lowered by the formation of a film of carbonate on the surface of the liquid. A concentrated solution of potassium hydroxide was tried and rejected because of the danger of its coming into contact with the fruit.

\* This work was carried out while the writer held a Commonwealth Research Studentship in the University of Sydney.

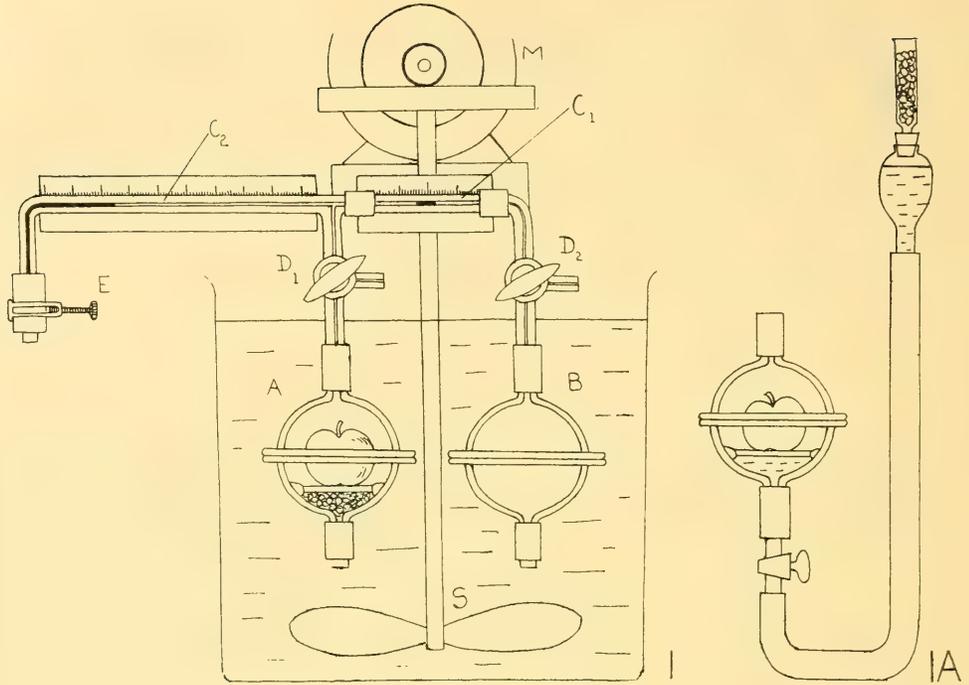


Fig. 1.

To measure the rate of oxygen uptake the following procedure is adopted:

The vessel, A, containing about 20 gm. of soda-lime, is disconnected from the tap,  $D_1$ . The two hemispheres are separated and the apple is placed on a small glass platform above the soda-lime. The hemispheres are then sealed together and connected to the apparatus. The taps are turned so that the atmosphere of each vessel is in contact with the external atmosphere. A period of at least  $1\frac{1}{4}$  hours is then allowed for the apparatus to come to the temperature of the water and for equilibrium to be established between the production of carbon dioxide from the fruit and its absorption by the soda-lime.

The taps are then turned so that the atmosphere in the respiration chamber, A, is connected with the mercury column and the index drop, and the compensating chamber, B, is connected with the index drop. After 5 minutes have been allowed for further equilibration, the drop is brought level with a fixed mark on the centre of tube  $C_1$ , by moving the mercury column in tube  $C_2$ . The time and the reading of the mercury on the scale are recorded.

After a period of 10–30 minutes, according to the magnitude of the rate of uptake of oxygen, the index drop is again adjusted to its original position. The difference between the final position of the mercury column and the original reading is used to calculate the decrease in volume which has occurred.

The whole procedure is then repeated without the carbon dioxide absorbent. The respiration chamber, A, is disconnected and the fruit removed. The fruit is transferred to an empty vessel which is connected to the apparatus in place of the previous vessel, A. Changes in volume are then measured in the same way as has been described for the determination of rate of uptake of oxygen.

If any decrease occurs in the volume of the air surrounding the apple ( $R.Q. < 1$ ), the index drop in C will be displaced to the left. Any increase in the volume of the atmosphere in the experimental vessel ( $R.Q. > 1$ ) results in a movement of the drop to the right. The difference between the position of the mercury after adjustment of the index drop at the end of the period, and its original position, gives the amount of decrease or increase which has occurred.

Where observations are being made on several fruits, many readings per day can be taken by the use of a large water-bath in which extra vessels, with apples enclosed, can be brought to equilibrium before being connected to the apparatus.

The changes in volume are measured at the temperature of the water-bath and the barometric pressure at the time of commencing an observation. By correcting for temperature and pressure, the rates of oxygen uptake and carbon dioxide production can be expressed in the desired units. In this paper they are expressed in mg./10Kg./hr.

The method of calculation is as follows:

Temperature of water-bath =  $t^{\circ}\text{C}$ .

Barometric pressure =  $p$  mm.

With  $\text{CO}_2$  absorbent.

Period of observation =  $m$  min.

Decrease in volume of air surrounding fruit  $\equiv X$  divisions on scale  $C_2$   
 $\equiv X \times C$  c.c. at  $t^{\circ}\text{C}$ . and  $p$  mm.

(Where  $C$  is the volumetric equivalent for 1 division on the scale,  $C_2$ .)

$$\therefore \text{Volume of oxygen consumed in 1 hour} = \frac{C \times X \times 60}{m} \text{ ml. at } t^{\circ}\text{C. and } p \text{ mm.}$$

Without  $\text{CO}_2$  absorbent.

Period of observation =  $m_1$  min.

Change in volume of air surrounding apple  $\equiv \pm X_1$  divisions on scale  $C_1$   
 $\equiv \pm X_1 \times C$  ml. at  $t^{\circ}\text{C}$ . and  $p$  mm.

$$\left. \begin{array}{l} \text{Increase} \\ \text{Decrease} \end{array} \right\} \text{ in volume in 1 hour} = \frac{C \times X_1 \times 60}{m_1} \text{ ml. at } t^{\circ}\text{C. and } p \text{ mm.}$$

$$\therefore \text{Volume of } \text{CO}_2 \text{ produced in 1 hour} = \frac{C \times X \times 60}{m} \pm \frac{C \times X_1 \times 60}{m_1} \text{ ml. at } t^{\circ}\text{C. and } p \text{ mm.}$$

$$\therefore \text{R.Q. of fruit} = \frac{\frac{C \times X \times 60}{m} \pm \frac{C \times X_1 \times 60}{m_1}}{\frac{C \times X \times 60}{m}}$$

Conversion of rates of oxygen uptake and carbon dioxide production from ml./hr. at  $t^{\circ}\text{C}$ . and  $p$  mm. to mg./10Kg./hr.

$$\text{Rate of oxygen uptake} = \frac{C \times X \times 60}{m} \times \frac{273}{273+t} \times \frac{p}{760} \times \frac{32}{22.4} \times \frac{10^4}{w} \text{ mg./10Kg./hr.}$$

$$\text{Rate of carbon dioxide production} = \left( \frac{C \times X \times 60}{m} + \frac{C \times X_1 \times 60}{m_1} \right) \times \frac{273}{273+t} \times \frac{p}{760} \times \frac{44}{22.4} \times \frac{10^4}{w} \text{ mg./10Kg./hr.}$$

(where 'w' is the weight of the fruit).

To test the efficiency of this method, comparisons were made between values of respiration rate obtained by this method and those obtained by the Pettenkofer method (Trout *et al.*, 1942) for apples whose respiration rates were known to be steady. Reasonably good agreement was obtained. Typical results are shown in Table 1.

TABLE 1.  
*Respiration Rate (mg.CO<sub>2</sub>/10Kg./hr.).*

Pettenkofer	..	..	..	..	155	154	98	96	91	115
Respirometer	..	..	..	..	147	163	97	98	105	123

As far as is known, this type of volumeter has not previously been used for measuring the respiration rate or respiratory quotient of apples. Most methods, such as those used by Magness and Diehl (1924), Haller and Rose (1932) and Platenius (1942) involve more elaborate apparatus and require longer periods of time for readings.

The advantages of the present method are:

- (1). It is independent of external temperature and pressure changes after the taps are closed to the atmosphere.
- (2). Owing to the shortness of the time required for the observation, there is no appreciable alteration either in the pressure or in the composition of the atmosphere surrounding the fruit while the observation is being made.
- (3). The apparatus is easily manipulated.
- (4). The short duration of the readings enables more accurate information to be gained where rates of carbon dioxide production and oxygen consumption are changing rapidly.

#### *Acknowledgements.*

The writer wishes to express thanks to Mr. M. C. Taylor, of the Council for Scientific and Industrial Research, Homebush, and Miss Frances M. V. Hackney, Linnean Macleay Fellow of the Society in Plant Physiology; also to other members of the Council for Scientific and Industrial Research, Homebush, and members of the Department of Botany, University of Sydney, for their helpful advice and criticism.

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## STUDIES IN THE METABOLISM OF APPLES.

IV. FURTHER STUDIES IN THE RESPIRATORY METABOLISM OF GRANNY SMITH APPLES,  
WITH SPECIAL REFERENCE TO THE IMPORTANCE OF OXYGEN SUPPLY.

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(From the Department of Botany, University of Sydney.)

(Ten Text-figures.)

[Read 26th July, 1944.]

Introduction.

The second paper of this series (Hackney, 1943) was concerned with the relationships between changes in the composition of the internal atmosphere and changes in the respiratory activity of mature Granny Smith apples. It appeared from the data from apples which had been stored for less than three or four months that the rate of output of carbon dioxide was governed by the internal oxygen concentration, and that this in turn was limited by the resistance of the skin of the fruit to the diffusion of oxygen from the surrounding air. In fruits which had been stored for more than five months the rate of output of carbon dioxide was not generally governed by the internal oxygen concentration.

In calculating the resistance of the skin to the passage of oxygen, the present writer assumed that the volume of oxygen utilized in respiration was approximately equal to that of carbon dioxide given off. During 1943, a new technique was adopted by means of which the rate of oxygen uptake was determined as well as the rate of carbon dioxide output. Two long series of experiments were carried out: the first on immature fruits which had not been in cool store; the second on apples of commercial maturity after various periods of cool storage. The results are presented in this paper.

In addition to the experiments on the respiration of apples in air, several experiments were carried out on the respiration of fruits in an atmosphere of pure oxygen. The results of these investigations add to the evidence of the importance of oxygen supply in the metabolism of stored apples.

MATERIALS AND METHODS.

All the apples were obtained from the same orchard at Orange, New South Wales. As the 1943 crop was very light the trees had not been thinned.

The immature apples used in the first series of experiments were taken from two selected trees: a sample of six fruits was taken from the trees each fortnight. On the day after picking, the fruits were put in a room maintained at 18.3°C., and the first observations were made twenty-four hours later. Subsequent observations were made every second day for two weeks. Great variability was observed in the respiratory behaviour of immature fruits. Several unsuccessful attempts were made to discover the cause of this variability. The first of these was an experiment in which four samples of six fruits were taken, two samples from each tree. One sample from each tree was composed of fruits which had developed in proximity to few leaves; the other sample was composed of fruits which had developed in proximity to many leaves. There was no difference in the variability in any of these samples. Within a sample there was no correlation between size of fruit and rate of respiration, whether expressed as milligrams per 10 Kilograms per hour or as milligrams per fruit per hour. A second experiment was designed to discover any differences (*a*) between fruits from the top

of the tree and those from the bottom of the same tree, and (b) between fruits from the part of the tree most exposed to sunlight and those from the most shaded part of the same tree. Again there was no difference in the mean level of respiration or variability in any of the four samples taken. It appears that the variability was not due to differences between the two trees nor to differences in position on the tree.

The apples used in the second series of experiments were of commercial maturity, picked on 30.iv.43. They were stored at 1°C. A sample of five fruits was withdrawn from store each fortnight and its subsequent respiratory behaviour was observed at 18.3°C. On most of the samples the observations were continued for at least four weeks, but in some of the later samples the fruits deteriorated within two weeks after removal from store, and observations were discontinued.

One experiment sought to discover whether there were differences in respiratory behaviour between mature apples from the two selected trees mentioned above (from which the immature fruits were taken) and apples which were taken from other trees in the same orchard to be used in the second series of experiments. No difference was detected. Variability between mature individuals was less marked than between immature individuals.

In the two long series of experiments the rates of oxygen uptake and carbon dioxide output were obtained with a respirometer of the type described by Sykes (1944). The first observations were begun about twenty-five hours after removal from store; assuming that the specific heat and thermal conductivity of apples approximate to those of water, calculations indicate that after this period the temperature at all points in the apple should be within 0.01°C. of the outside temperature, 18.3°C. Such slight differences in temperature would not have caused inaccuracy in the respirometer readings.

In the series of experiments with apples in pure oxygen this gas was passed through the apparatus from a cylinder. It was first blown through baryta water and shown to contain no carbon dioxide; it was then passed through the respiration vessels and the rate of carbon dioxide output was measured by the Pettenkofer method. Rates of oxygen uptake were not obtained.

The concentrations of oxygen and carbon dioxide in the internal atmosphere were measured by the method described in the first paper of this series. (Trout *et al.*, 1942).

#### EXPERIMENTAL RESULTS. A.—IMMATURE FRUITS AT 18.3°C.

Table 1 shows date of picking, date of insertion of gas-sampling pipette,\* date of first observation and date of final observation for each of the nine samples taken.

TABLE 1.  
*Immature Granny Smith Apples of the 1941-1942 Season.*

Sample No.	Date of Picking.	Date of Setting Up.	Date of First Observation.	Date of Final Observation.
1a	7.xii.42	8.xii.42	9.xii.42	21.xii.42
2a	21.xii.42	22.xii.42	23.xii.42	4.i.43
3a	4.i.43	5.i.43	6.i.43	18.i.43
4a	18.i.43	19.i.43	20.i.43	26.i.43
5a	15.ii.43	16.ii.43	17.ii.43	1.iii.43
6a	1.iii.43	2.iii.43	3.iii.43	16.iii.43
7a	15.iii.43	16.iii.43	17.iii.43	30.iii.43
8a	29.iii.43	30.iii.43	31.iii.43	13.iv.43
9a	13.iv.43	14.iv.43	15.iv.43	29.iv.43

*Respiration Rates.*—When rates of oxygen uptake and carbon dioxide output were calculated in mg./10Kg./hr., those of the earlier samples were very much higher than the corresponding rates for mature fruits. The mean initial rates decreased as development proceeded; and in samples 7, 8 and 9, they were very much the same as those of the mature samples which followed (see Fig. 1). However, it has been suggested (Kidd, 1935; Clendenning, 1942) that, when comparisons are to be made between fruits at

\* To sample the internal atmosphere of the fruit, i.e., the atmosphere in the intercellular space system.

various stages of development, respiration rates should be calculated in units of gas taken up or given off per fruit, rather than per unit weight. Cell division ceases when the apple is about 3 cm. in diameter (Smith, 1940); further increase in size is due to cell enlargement, which is the result of enlargement of the vacuoles rather than of increase in the volume of the protoplasmic contents of the cell. Thus it is possible that for a single cell, the amount of actively respiring material is the same in an immature apple weighing 30 gm. as in a mature apple weighing 150 gm.

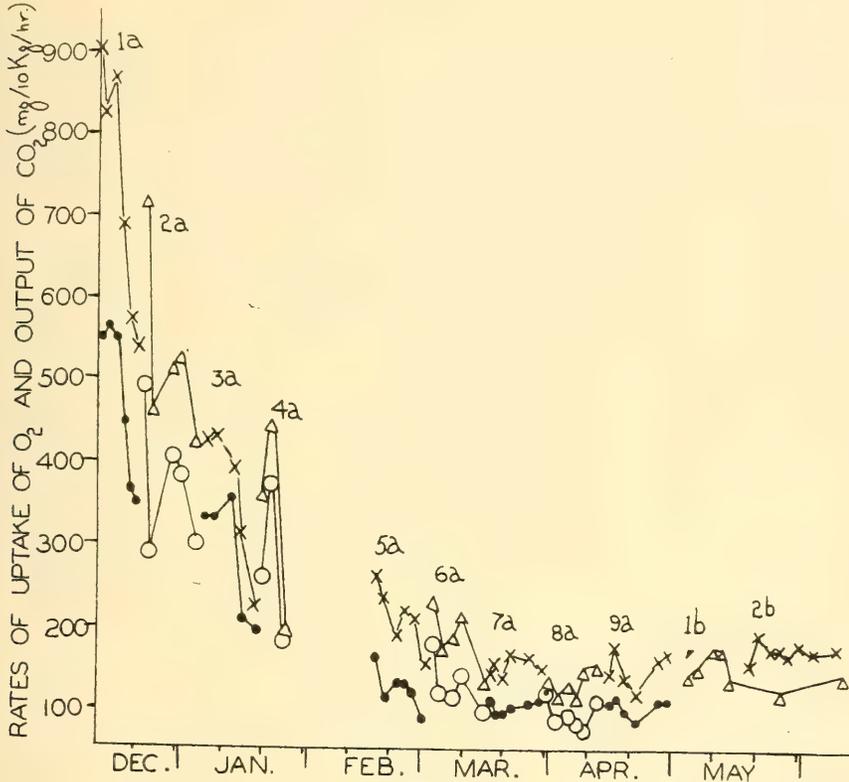


Fig. 1.—Graph showing the mean rates of oxygen uptake and carbon dioxide output per unit weight for each of the samples of immature Granny Smith apples (1a to 9a inclusive), and the mean rates of carbon dioxide output for the first two mature samples (1b and 2b). Values for rate of oxygen uptake are indicated by black spots and white circles for alternate samples; values for rate of carbon dioxide output are indicated by crosses and triangles for alternate samples.

Of the immature samples studied, number 1a (average diameter 3.2 cm.; average weight 17 gm.) was the only one in which cell division might not have ended. In sample 2a (average diameter 4.1 cm.; average weight 32 gm.) cell division can be presumed to have ended. Figure 2 shows mean initial rates of oxygen uptake and carbon dioxide output, calculated in units per fruit, for all the samples of mature and immature fruits. The pronounced difference in the behaviour of immature and mature fruits, which was apparent when respiration rates were calculated in units of gas taken up or given off per unit weight (Fig. 1), is not evident when they are calculated in units per fruit. The mean initial rates did not change significantly as development proceeded (Fig. 2). N. O'Grady, working with immature Granny Smith apples in 1941, found that the rate of carbon dioxide output decreased as development proceeded when calculated per unit weight, but appeared to increase when calculated per fruit.\*

\* Unpublished data, Department of Botany, University of Sydney.

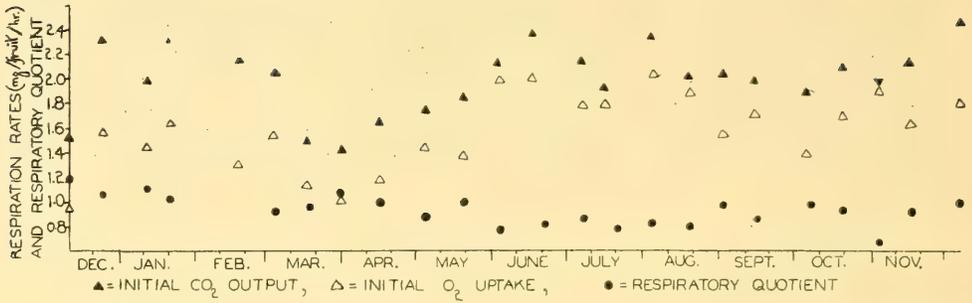


Fig. 2.—Graph showing the mean initial rates of oxygen uptake per fruit, carbon dioxide output per fruit, and mean initial values for respiratory quotient for all the samples of immature and mature Granny Smith apples. The first of the mature samples was taken in the first week of May, 1943.

The rates of uptake of oxygen and output of carbon dioxide for individual fruits generally fell, but fluctuations occurred. It is unlikely that the greatest of these fluctuations were analogous to the 'climacteric rise', since they were not accompanied by any signs of ripening. They were probably analogous to the 'pre-climacteric humps' described by Krotkov (1941).

The respiratory quotient was approximately 1 throughout the period of observation.

*Composition of the Internal Atmosphere.*—Figure 3 shows the mean concentrations of oxygen and carbon dioxide present in the internal atmospheres of the various samples. In the earliest samples the concentration of oxygen was very high (about 20%) and that of carbon dioxide was low (about 1%). In later samples the concentration of oxygen was about 2% lower, and that of carbon dioxide was about 1% higher, than in earlier samples. Compared with the values obtained later for mature fruits, the concentration of oxygen in immature fruits was always high and that of carbon dioxide low.

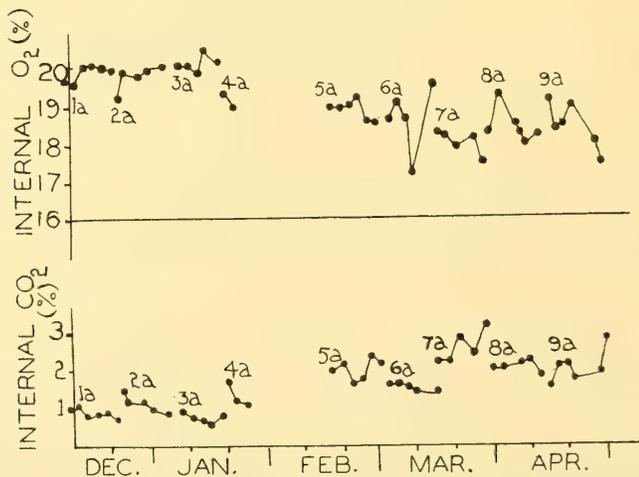


Fig. 3.—Graphs showing the mean internal concentrations of oxygen and carbon dioxide for each of the samples of immature Granny Smith apples taken in 1942-43.

*Resistance of the Skin to Gaseous Diffusion.*—It has been suggested (Wardlaw and Leonard, 1936) that the fall in respiration rate as development proceeds might be due in some measure to the reduction of the surface-volume ratio ( $s/v$ ) which takes place as the fruit enlarges. The immature fruit is almost spherical and the reduction in  $s/v$  consequent upon each small increase in diameter is greater in the early samples; in the

later samples the reduction is smaller (Fig. 4). This means that as the apple enlarges it becomes more difficult for the oxygen required for respiration to enter the fruit and for the carbon dioxide produced to escape. This might be expected to result in a decreased concentration of oxygen and an increased concentration of carbon dioxide in the internal atmosphere, as development proceeds, and these have, in fact, been observed (Fig. 3). However, a study of the changes in the resistance of the skin to

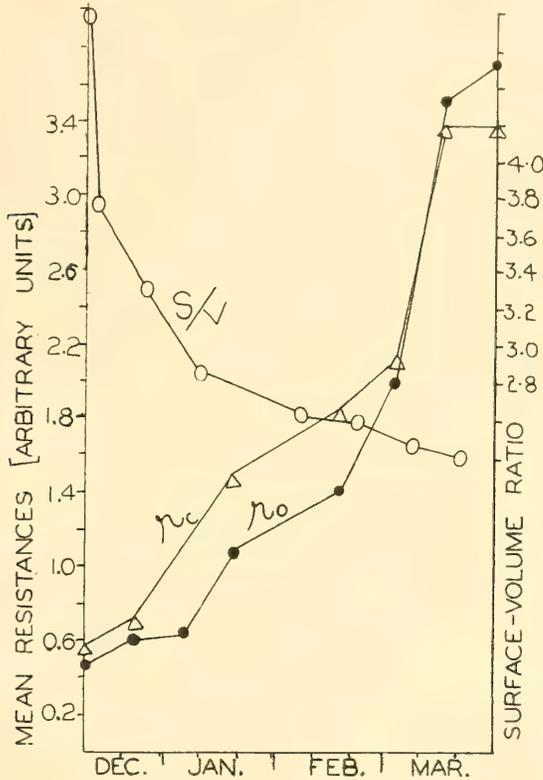


Fig. 4.—Graph showing the surface-volume ratio ( $s/v$ ) and the mean initial values for resistances (per unit surface) to the diffusion of oxygen ( $r_o$ ) and carbon dioxide ( $r_c$ ) in each of the samples of immature apples taken in 1942-43.

gaseous diffusion shows that reduction in  $s/v$  from sample to sample is not the complete explanation of the changes which occur. Previous papers (Trout *et al.*, 1942; Hackney, 1943) have dealt exclusively with mature fruits which were of such a volume that small differences in size did not cause appreciable changes in the value of  $s/v$ . The formulae used for the calculation of the resistances of the skin per unit area to the passage of oxygen ( $r_o$ ) and of carbon dioxide ( $r_c$ ) are:

$$r_o = \frac{\delta O + 0.2 \delta N}{qR} \quad \text{and} \quad r_c = \frac{\delta C}{qR},$$

where  $R$  is the rate of production of carbon dioxide in c.c. given off per sq. cm. per unit of time,  $qR$  is the corresponding amount of oxygen absorbed, and  $\delta O$ ,  $\delta N$  and  $\delta C$  are the differences in concentrations of oxygen, nitrogen and carbon dioxide, respectively, between the internal atmosphere of the fruit and the external atmosphere. These formulae give  $r_o$  and  $r_c$  in arbitrary units. For comparisons between mature fruits, where  $s/v$  does not vary greatly with small variations in size, it is not necessary to calculate  $R$  in c.c. per unit surface; the rate of output of carbon dioxide per unit weight can be used instead. This has been done in previous papers and will be done again in this paper in the section on mature fruits. It is necessary to calculate rates of uptake

and output of gases in units per unit surface in order to compare skin resistances in immature fruits where  $s/v$  is changing rapidly. This method gives the resistance of the skin per unit surface and eliminates the surface-volume ratio. Fig. 4 shows that both  $r_o$  and  $r_c$  increased as development proceeded in the immature fruits of 1942-43. Thus there is another factor, apart from changes in surface-volume ratio, causing the resistance of the fruit to gaseous diffusion to increase as development proceeds.

It must be remembered that the figures for  $r_o$  and  $r_c$  in immature apples are in different units from those which will be presented later for mature apples; the two sets of figures may only be compared qualitatively although different values within each group, being in the same units, may be compared quantitatively.

#### EXPERIMENTAL RESULTS. B.—MATURE FRUITS AT 18.3°C.

Table 2 shows date of removal from store and insertion of gas-sampling pipette, date of first observation, date of final observation, and number of weeks in cool store, for each of the fifteen samples taken during 1943.

TABLE 2.

Sample No.	Date of Removal from Store.	Date of First Observation.	Date of Final Observation.	Number of Weeks in Cool Store.
1b	3.v	4.v	5.vii	0
2b	18.v	19.v	20.vii	2
3b	1.vi	2.vi	22.vii	4
4b	15.vi	16.vi	22.vii	6
5b	6.vii	7.vii	17.viii	9
6b	20.vii	21.vii	26.viii	11
7b	2.viii	3.viii	9.ix	13
8b	18.viii	19.viii	28.x	15
9b	31.viii	1.ix	21.x	17
10b	14.ix	15.ix	28.x	19
11b	5.x	6.x	18.xi	22
12b	19.x	20.x	25.xi	24
13b	2.xi	3.xi	30.xi	26
14b	16.xi	17.xi	6.xii	28
15b	7.xii	8.xii	20.xii	31

*Respiration Rate.*—The mean rates of oxygen uptake and carbon dioxide production for the fifteen samples of mature apples are shown in Figs. 5 and 6 respectively. Most

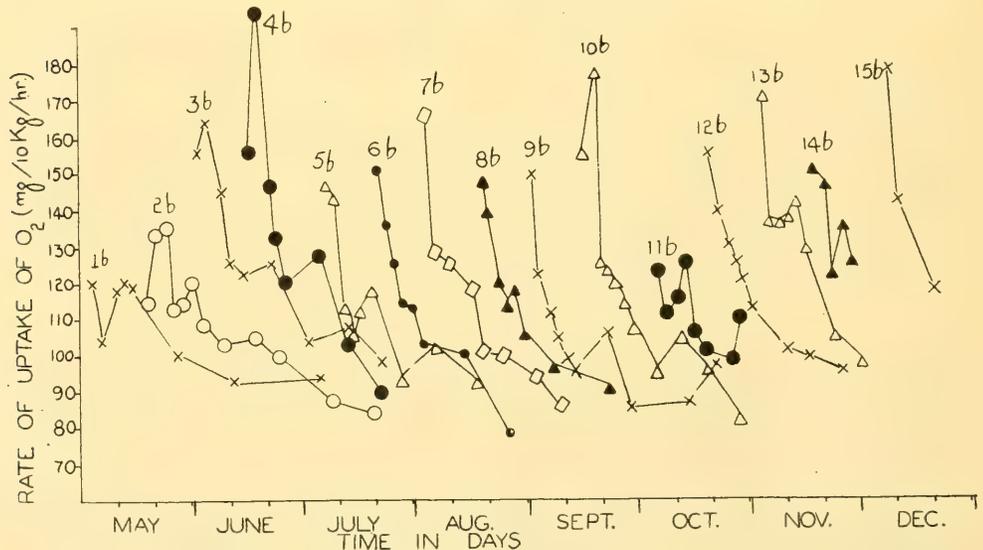


Fig. 5.—Graph showing the mean rates of uptake of oxygen (per unit weight) for each of the thirteen samples of mature Granny Smith apples taken during 1943.

of the early curves for rate of output of carbon dioxide by mature fruits showed distinct peaks during the first week after removal from store, after which they fell more or less steadily throughout the period of observation. The peaks occurred in the curves for most individuals within each sample. The curves for mean rate of uptake of oxygen frequently showed no peaks. When a peak was present, it was usually less distinct than the corresponding peak for output of carbon dioxide. This was due to the fact that fewer individuals showed peaks for uptake of oxygen than for output of carbon dioxide. Some individuals showed peaks for both rates, some showed no peaks, and the rest showed a peak for rate of output of carbon dioxide but no peak for uptake of oxygen. In the last type, the respiratory quotient was initially less than 1, but rose to approximately 1 when the peak was observed. No individual showed a significant peak for rate of uptake of oxygen without a corresponding peak for output of carbon dioxide.

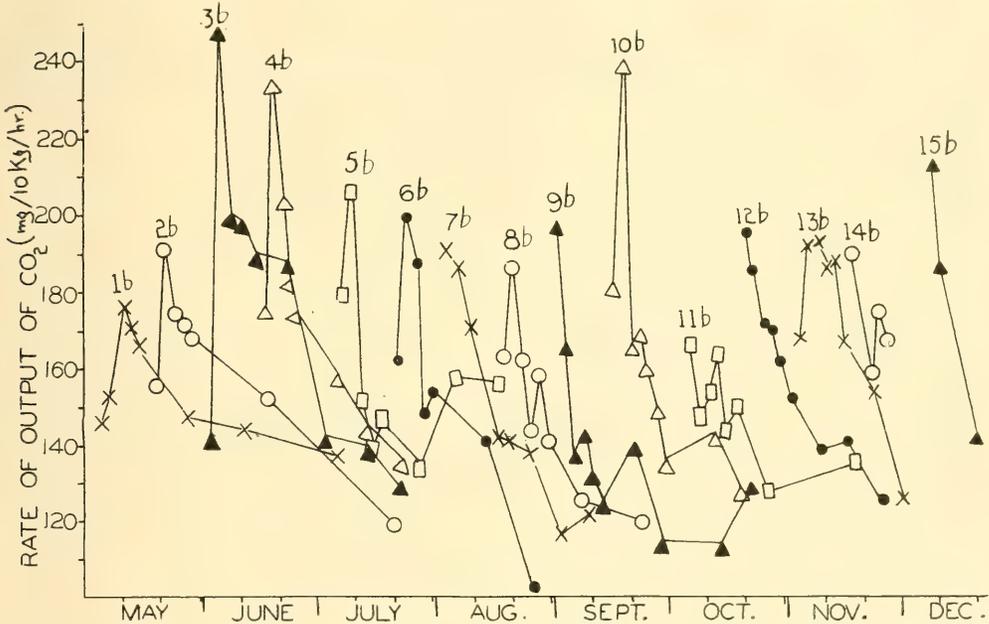


Fig. 6.—Graph showing the mean rates of output of carbon dioxide (per unit weight) for each of the thirteen samples of mature Granny Smith apples taken during 1943.

The mean initial rates of uptake of oxygen and output of carbon dioxide showed no definite trends.

Mean values for the respiratory quotient are shown in Fig. 7. Only the first few values for each sample are included in the figure as no change occurred subsequently. The initial value was frequently less than 1 on the first day after removal from store but had risen to approximately 1 when the second reading was taken. The reason for the low initial respiratory quotient is not known. Possible inaccuracies which might

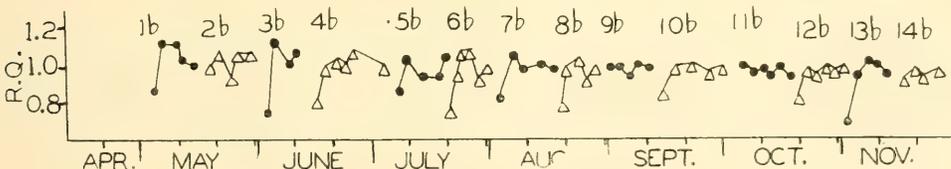


Fig. 7.—Graph showing the mean values for the respiratory quotient in each of the samples of mature Granny Smith apples taken during 1943. The curves have been curtailed, as no further change was observed in the respiratory quotient of any of the samples.

occur as a result of incomplete temperature equilibration (e.g., inaccuracies due to liberation of dissolved or adsorbed carbon dioxide at the higher temperature) would tend to increase the respiratory quotient, not decrease it.

*Composition of the Internal Atmosphere.*—The mean concentrations of oxygen and carbon dioxide present in the internal atmospheres of the fifteen samples are shown in Fig. 8. In the first seven samples the internal oxygen concentration fell throughout the period of observation. The corresponding concentration of carbon dioxide rose slightly in samples 1*b* to 4*b* but remained steady or fell in samples 5*b* to 7*b*. In samples 8*b* and 9*b* the changes observed in the internal oxygen concentration were relatively slight; the corresponding concentration of carbon dioxide fell; in the last samples (10*b* to 15*b*) oxygen concentration either remained constant or rose slightly. The corresponding concentration of carbon dioxide remained constant or fell.

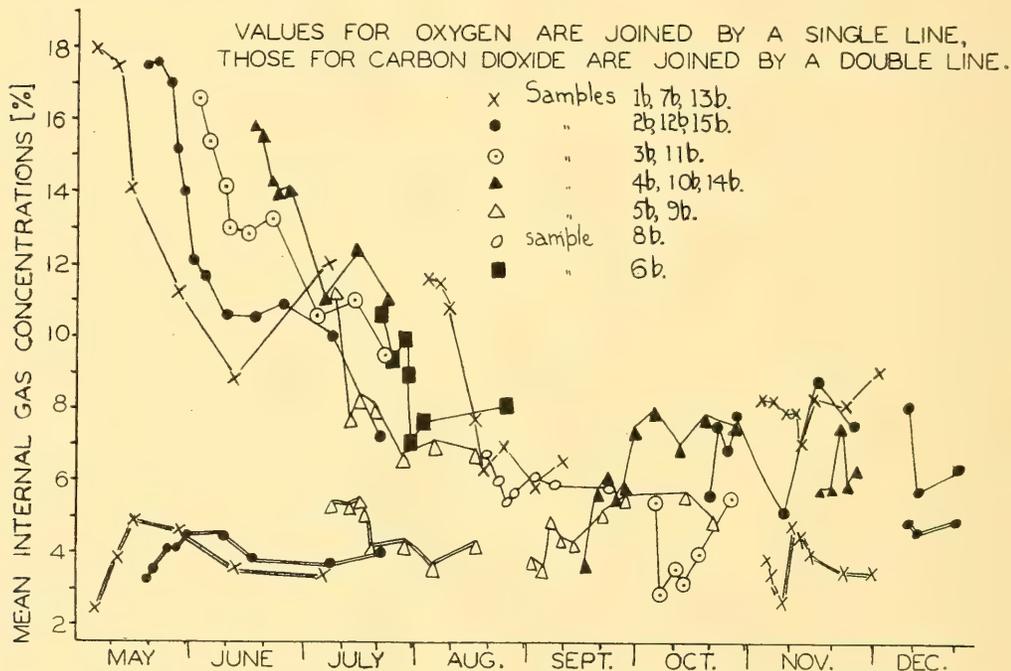


Fig. 8.—Graph showing the mean internal oxygen concentrations for all the samples of mature Granny Smith apples and the mean internal carbon dioxide concentrations for typical early and late samples of mature Granny Smith apples of the 1943 season.

The mean initial oxygen concentration decreased from sample to sample until 10*b* was reached. The initial oxygen concentrations of the later samples were higher than that of 10*b*, those of 13*b* and 15*b* being the highest. The corresponding concentrations of carbon dioxide tended to rise from sample to sample until 10*b* was reached. In this sample the initial concentration of carbon dioxide was higher than that of oxygen. In the later samples no further rise was observed.

*Resistance of the Skin to Gaseous Diffusion.*—The mean resistances of the skin to the diffusion of oxygen and carbon dioxide are shown in Fig. 9. The mean resistance to the diffusion of oxygen ( $r_o$ ) increased markedly in all the early samples (1*b* to 9*b* inclusive). In sample 10*b* it remained constant; in later samples it rose, although generally less steeply than in the early samples. The mean initial value for  $r_o$  tended to rise from sample to sample, reaching a maximum with sample 10*b*. For later samples it tended to fall, the lowest value being that of sample 13*b*.

The mean resistance of the skin to the diffusion of carbon dioxide ( $r_c$ ) increased in most of the early samples. In later samples it remained constant. The initial values

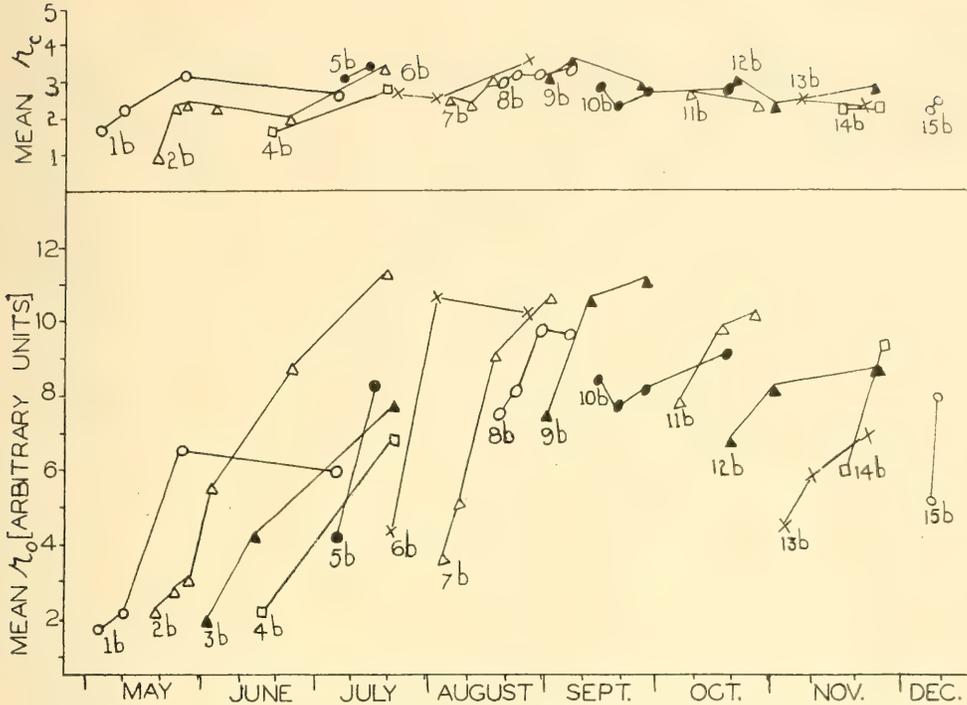


Fig. 9.—Graph showing mean resistances to the diffusion of oxygen ( $r_o$ ) and carbon dioxide ( $r_c$ ) for each of the samples of mature Granny Smith apples taken in 1943. The arbitrary units used here are not the same as those used in Fig. 4.

for  $r_c$  were highest in the samples which had the highest initial values for  $r_o$ . The regression coefficient of  $r_c$  on  $r_o$  was 1.14 and was significant ( $P < 0.02$ ).

EXPERIMENTAL RESULTS. C.

*The Behaviour of Fruits in an Atmosphere of Pure Oxygen.*—During 1943, six experiments were carried out to determine the rate of output of carbon dioxide of immature and mature apples when surrounded by an atmosphere of pure oxygen.

In the first experiment, twelve immature fruits were used which were comparable with those of sample 8a. Table 3 shows the rates of output of carbon dioxide when the fruits were in air and when they were in pure oxygen.

It is clear that, in fruits at the particular stage of development used, increased oxygen supply had no effect on the rate of output of carbon dioxide. These fruits were of the same age as those of sample 8a, in which the mean internal concentrations of carbon dioxide and oxygen were about 2.5% and 18.5%, respectively, and the mean values for  $r_c$  and  $r_o$  were very low (less than 2 units, whether calculated on respiration per unit weight or on respiration per unit surface).

The other five experiments with pure oxygen (numbers 2 to 6, inclusive) were carried out with mature apples at 18.3°C. In the second experiment fruits from samples 1b and 4b were used. The experiment was begun on 28.vi.43. Sample 1b had been held at 18.3°C. since 4.v.43 and sample 4b had been at 18.3°C. since 16.vi.43. Table 4 shows the rates of output of carbon dioxide under various conditions.

Increased oxygen supply did not have a great effect on fruit 1 of sample 4b, but the rates of output of carbon dioxide of the other fruits rose considerably. Thus, even in fruits which had been held at 18.3°C. for eight weeks (sample 1b), oxygen supply was apparently limiting respiration rate. It appears that the substrate factor suggested by Blackman and Parija (1928) had not assumed control. The values for  $r_o$  for fruits 1 and 2 of sample 1b and fruit 1 of sample 4 were high (12.0, 7.4 and 6.4 units, respectively,

TABLE 3.  
*First Experiment with Pure Oxygen; Immature Fruits of the Same Age as those of Sample 8a.*

Date.	No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)
31.iii.43	1	Air.	133	7	Air.	144
11.25 a.m.-	2		130	8		129
4.10 p.m.	3		115	9		112
	4		119	10		137
	5		163	11		139
	6		140	12		143
31.iii-1.iv Overnight.	1 to 6	Oxygen.	Not observed.	7 to 12	Air.	Not observed.
1.iv	1	Oxygen.	126	7	Air.	106
10.30 a.m.-	2		115	8		199
3.30 p.m.	3		96	9		115
	4		93	10		118
	5		115	11		122
	6		108	12		125
1-2.iv	1	Oxygen.	110	7	Air.	111
3.30 p.m.-	2		105	8		102
10.30 a.m.	3		102	9		100
	4		90	10		99
	5		100	11		116
	6		98	12		119
2.iv	1	Oxygen.	136	7	Air.	122
10.35 a.m.-	2		111	8		118
4.5 p.m.	3		122	9		115
	4		113	10		118
	5		103	11		133
	6		108	12		130

TABLE 4.  
*Second Experiment with Pure Oxygen; Mature Fruits of Samples 1b and 4b.*

Date.	Sample No. and No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .	Sample No. and No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .
28.vi.43	1b-1	Air.	105	—	1b-3	Air.	116	—
	1b-2		108	—	1b-4		105	—
	4b-1		153	—	4b-3		153	—
	4b-2		166	—	4b-4		—	—
28-29.vi	1b-1 to 4b-2	Oxygen.	Not observed		1b-3 to 4b-4	Air.	Not observed.	
29.vi	1b-1	Oxygen.	126	20	1b-3	Air.	113	—
9.35 a.m.-	1b-2		102	0	1b-4		98	—
3.35 p.m.	4b-1		135	—	4b-3		112	—
	4b-2		151	—	4b-4		129	—
29-30.vi	1b-1	Oxygen.	147	39	1b-3	Air.	118	2
3.35 p.m.-	1b-2		135	25	1b-4		111	6
noon.	4b-1		167	10	4b-3		130	-15
	4b-2		201	12	4b-4		131	—
30.vi-1.vii	1b-1	Oxygen.	149	42	1b-3	Air.	121	4
4 p.m.-	1b-2		130	17	1b-4		102	4
9.45 a.m.	4b-1		170	10	4b-3		129	-15
	4b-2		185	12	4b-4		132	—
1-2.vii	1b-1	Oxygen.	131	25	1b-3	Air.	117	0
9.45 a.m.-	1b-2		158	21	1b-4		116	2
9.45 a.m.	4b-1		157	3	4b-3		140	-9
	4b-2		199	20	4b-4		136	—

calculated on respiration per unit weight). The value for fruit 2 of sample 4 was not obtained.

In the third experiment, fruits 1, 2, 3 and 4 of sample 1*b* were used again, this time with fruits 1, 2, 3 and 5 of sample 7. Sample 1*b* had been out of store for fourteen weeks and sample 7*b* had been out of store for one week. Air was passed through all the vessels on 10-11.viii.43 and oxygen was supplied to four of the fruits from the morning of 11.viii. The rates of output of carbon dioxide by these four fruits rose slowly until 13.viii., when the experiment was concluded. Table 5 gives the most relevant data.

TABLE 5.  
*Third Experiment with Pure Oxygen; Mature Fruits of Samples 1b and 7b.*

Date.	Sample No. and No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .	Sample No. and No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .
10-11.viii.43	1 <i>b</i> -1	Air.	123	—	1 <i>b</i> -3	Air.	126	—
	1 <i>b</i> -2		107	—	1 <i>b</i> -4		107	—
	7 <i>b</i> -1		162	—	7 <i>b</i> -3		147	—
	7 <i>b</i> -2		173	—	7 <i>b</i> -5		168	—
13.viii	1 <i>b</i> -1	Oxygen.	172	40	1 <i>b</i> -3	Air.	128	0
	1 <i>b</i> -2		139	30	1 <i>b</i> -4		116	8
	7 <i>b</i> -1		224	39	7 <i>b</i> -3		140	-5
	7 <i>b</i> -2		201	16	7 <i>b</i> -5		169	0

Even after being held at 18.3°C. for fourteen weeks, the fruits of sample 1*b* showed a considerable rise in respiration rate when pure oxygen was supplied.

In the fourth experiment, fruits of sample 12*b*, which had been out of store for two weeks, were used. Table 6 shows the increase which occurred in the rate of production of carbon dioxide. The mean value for  $r_0$  in these fruits was 7.9 units.

TABLE 6.  
*Fourth Experiment with Pure Oxygen; Mature Fruits of Sample 12b.*

Date.	No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .	No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .
2-3.xi.43 12.15 p.m.- 9.15 a.m.	1	Air.	163	—	4	Air.	160	—
	2		145	—	5		151	—
	3		140	—				
3-4.xi 9.30 a.m.- 10 a.m.	1	Oxygen.	201	23	4	Air.	169	5.6
	2		154	6.2	5		141	-6.6
	3		145	3.6				
4-5.xi 10 a.m.- 9.30 a.m.	1	Oxygen.	207	27	4	Air.	154	-3.8
	2		164	13.1	5		136	-10
	3		162	15.7				
5.xi 9.30 a.m.- 4.15 p.m.	1	Oxygen.	214	30.7	4	Air.	145	-9.4
	2		176	21.5	5		131	-13.8
	3		169	20.8				

The fifth experiment was similar to the fourth, but the fruits used were those of sample 14*b*, which had been held at 18.3°C. for nearly two weeks. The mean value for  $r_0$  was 9.5 units. When three of the fruits had been in oxygen for 48 hours the highest increase observed in the rate of output of carbon dioxide was 14.4% for apple 1. This

was not a significant response, since the corresponding rate for fruit 5 in air rose 16.7% during the same period. When the three fruits had been in oxygen for 72 hours, the rise in respiration rate was only slightly higher than the rise in respiration rate of fruit 5 which was still in air (see Table 7).

TABLE 7.  
*Fifth Experiment with Pure Oxygen; Mature Fruits of Sample 14b.*

Date.	No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .	No. of Fruit.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .
29-30.xi.43	1	Air.	125	—	4	Air.	182	—
12.30 p.m.—	2		149	—	5		114	—
9.30 a.m.	3		144	—				
30.xi-1.xii	1	Oxygen.	130	4	4	Air.	176	-3.3
9.35 a.m.—	2		165	10.8	5		150	29
9.20 a.m.	3		159	10.4				
1-2.xii	1	Oxygen.	143	14.4	4	Air.	172	-5.5
9.20 a.m.—	2		161	8.0	5		133	16.7
9.20 a.m.	3		158	9.7				
2-3.xii	1	Oxygen.	148	17.0	4	Air.	170	-6.6
9.20 a.m.—	2		180	20.8	5		134	17.5
9.20 a.m.	3		187					

The sixth experiment was similar to the fourth and fifth, using fruits of samples 14b and 15b, which had been at 18.3°C. for three and a half weeks and five days, respectively. The mean value for  $r_0$  was 8.2 units. Owing to trouble with the manipulation of the oxygen supply, no reliable observations were made until the fruits had been in oxygen for more than 50 hours. Table 8 gives the relevant data. The increased oxygen supply had no significant effect on the rate of output of carbon dioxide after 50 hours.

TABLE 8.  
*Sixth Experiment with Pure Oxygen; Mature Fruits of Samples 14b and 15b.*

Date.	Sample No. and Individual.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .	Sample No. and Individual.	Surrounding Atmosphere.	Output of CO <sub>2</sub> (mg./10 Kg./hr.)	% Increase in Rate of Output of CO <sub>2</sub> .
13-14.xii.43	14b-2	Air.	110	—	14b-3	Air.	107	—
12.30 p.m.—	15b-2		187	—	15b-4		224	—
10.20 a.m.	15b-3		119	—	15b-5		163	—
14-15.xii	14b-2	Oxygen.	—	—	14b-3	Air.	128	19.6
10.45 a.m.—	15b-2		—	—	15b-4		236	5.4
2.15 p.m.	15b-3		—	—	15b-5		174	6.8
16-17.xii	14b-2	Oxygen.	126	14.5	14b-3	Air.	117	9
4 p.m.—	15b-2		193	3.2	15b-4		214	-4.5
9.45 a.m.	15b-3		180	13.5	15b-5		171	4.9

In all the experiments where the rate of production of carbon dioxide increased in pure oxygen, the normal level had been regained when observations were made two days after the apples were returned to air.

Figure 10 shows the mean rates of output of carbon dioxide for the apples in air and for those in oxygen in each of the six experiments.

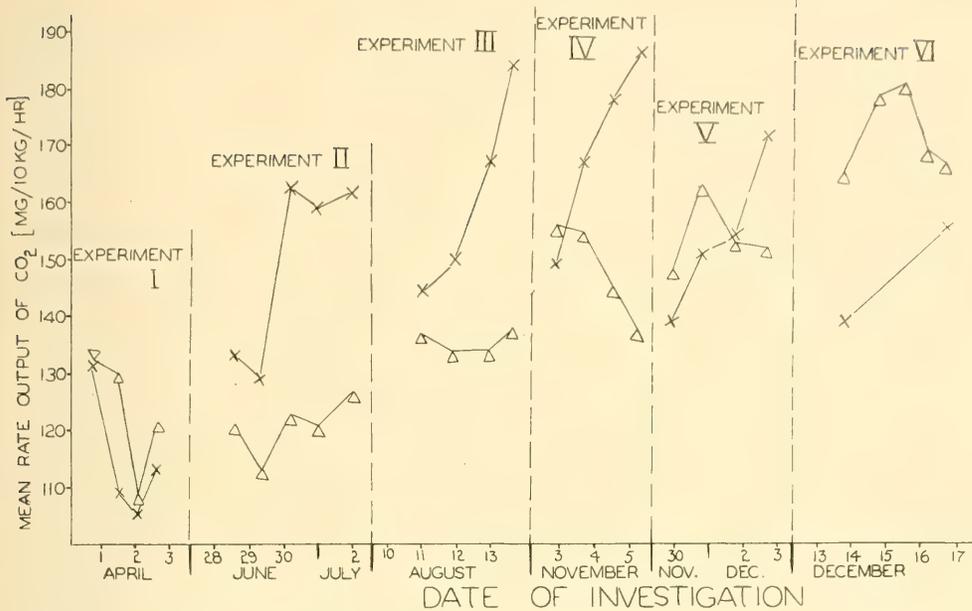


Fig. 10.—Graphs showing the effect of pure oxygen on the rate of carbon dioxide output of Granny Smith apples of the 1943 season at 18.3°C. In each experiment crosses represent values for fruits placed in oxygen after the first observation had been made, and triangles represent values for fruits held in air throughout the period of observation. Immature fruits were used in the first experiment; mature fruits which had been in cool store for various periods were used in the other experiments.

#### DISCUSSION OF RESULTS.

*Discussion of the Behaviour of Immature Fruits.*—When respiration rates were calculated in milligrams of oxygen taken up or carbon dioxide given off per 10 Kg. per hour, a pronounced decrease in respiratory activity was apparent as development proceeded (Fig. 1). When the same rates were calculated in milligrams per fruit per hour (i.e., when an attempt was made to base respiration rate on amount of respiring material present), the decrease in respiratory activity was not evident. The method of calculation of the respiration rate using the whole fruit as a unit is, of course, open to the objection that different fruits contain different numbers of cells and different amounts of protoplasm. However, in the absence of further data, the figures used should give a reasonable approximation for the comparison of the rates of respiration per unit respiring material for fruits at different stages of development. In future work a closer approximation could be obtained by calculating respiration rate on the basis of total protein or total nitrogen present in each fruit.

The decrease in initial respiration rate per unit weight as development proceeds has been observed in Jonathan apples by Shaw (1942), and in McIntosh and Northern Spy apples by Krotkov (1941). Shaw observed a rise in rate of uptake of oxygen extending over a short time after fruit setting, followed by a decrease as the fruit developed. Krotkov observed a decrease in initial rate of production of carbon dioxide from the time of fruit setting until within a few weeks of picking. As no data have been obtained for Granny Smith apples until some time after fruit setting, it is not known whether the respiration rate per unit weight increases during the initial period in this variety. It is possible that the respiratory trends observed by Shaw and Krotkov might have been quite different had the respiration rates been calculated in units per fruit instead of per unit weight.

Mention has already been made of some of the physiological effects which might result from changes in surface-volume ratio and in the resistance of the skin to gaseous diffusion during development. The effect of changes in the surface-volume ratio could

not be directly observed. It has been shown that even when the surface-volume factor is eliminated from the calculations, appreciable changes occur in the resistance of the skin of the fruit to the diffusion of oxygen and carbon dioxide. Changes in surface-volume ratio and changes in the resistance of the skin could only affect the respiration rates by modifying the concentrations of oxygen and carbon dioxide in the internal atmosphere. The observed changes in the internal atmosphere were small. In addition, the lack of any change in the respiration rate when immature fruits were held in pure oxygen proves that at that stage the respiration rate was not limited by oxygen supply. The resistance changes observed in the immature fruit could not, therefore, have had any effect on the respiration rates.

The shapes of the respiration curves for immature fruits are probably influenced by other factors, and it would be of little use to speculate further until more information has been obtained.

#### COMPARISON OF THE RESULTS FOR MATURE FRUITS OF 1943 WITH THOSE OF PREVIOUS YEARS.

*Rates of Output of Carbon Dioxide.*—The shape of the curves for early samples for mean rate of output of carbon dioxide (Fig. 4) is somewhat different from that of the corresponding curves obtained during 1941 and 1942 (Hackney, 1943). The latter, although showing fluctuations from time to time, did not exhibit any disturbance great enough or of long enough duration to be compared with the climacteric rise observed in some varieties of apples and in other fruits by Blackman and Parija (1928), Wardlaw and Leonard (1936) and other workers. Many of the curves obtained during 1943 showed a distinct increase in the rate of output of carbon dioxide within the first week after removal from store. In 1943 the first observation was always made on the first day after removal from store and the second observation was generally made two days later, no observation being made on the second day after removal from store. The 1941 experiments were begun similarly, but in 1942 the first observation was not generally made until the second day after removal from store (Hackney, 1943). In the early samples for 1943 the first reading was often considerably lower than the second. In corresponding samples for 1941 and 1942 the first reading was generally the highest observed. It is possible that the respiration rates were lower on the first day after removal from store in 1942, as in 1943, and that the lack of observations earlier than the second day after removal from store was responsible for the difference in the shape of the curves. If the first reading were omitted for each of the 1943 samples, the curves would be very similar to those obtained in 1941. It is probable that the 1941 fruits were more mature than the 1943 fruits at the time of picking, and had passed through the phase of rising respiration rate while still on the tree.

*Composition of the Internal Atmosphere.*—The changes which took place in the composition of the internal atmospheres of the early samples of mature fruits in 1943 were very similar to those which took place in corresponding samples of the 1941 and 1942 seasons (Hackney, 1943). The later samples for 1943 differed from those of 1941 and 1942 in that the mean concentration of oxygen in the internal atmosphere did not generally rise during the period of observation. Even when an increase was observed (samples 9 and 10), its magnitude was relatively small (3.8% to 7.7%) compared with those observed in previous years (6% to 15% in 1941 and 5% to 13% in 1942).

*Resistance of the Skin to Gaseous Diffusion.*—As in 1941 and 1942 (Hackney, 1943), the mean values for  $r_o$  in the early samples increased throughout the period of observation. But in 1941 and 1942,  $r_o$  remained constant or decreased in the later samples, whereas it continued to increase in the corresponding samples for 1943. Number 10 was the only 1943 sample in which  $r_o$  did not increase.

As in 1941 and 1942, changes in  $r_c$  were much less noticeable than changes in  $r_o$ . A slight increase over the period of observation was generally observed in the early samples. In the later samples,  $r_c$  remained approximately constant.

*Respiratory Quotient.*—The respiratory quotient was not measured in 1941 or 1942. In order to calculate  $r_o$  in the previous papers of this series, the value for the respiratory quotient was assumed to be approximately 1. The values obtained for the respiratory

quotient during 1943 indicate that in normal fruits any variations from this value are so slight as not to affect the shape of the curves for  $r_0$ . In 1941-42, it was suspected that a small amount of anaerobic respiration occurred in air when the internal oxygen concentration was low. If that was true during 1943, the amount of carbon dioxide produced anaerobically must have been too small to alter the respiratory quotient noticeably.

#### GENERAL DISCUSSION OF BEHAVIOUR OF MATURE FRUITS.

*Respiration Rates.*—The data obtained for mature fruits during 1943 present problems which were not indicated in those obtained during 1941-42. The occurrence of what is possibly analogous to the 'climacteric rise' in the early curves for rate of output of carbon dioxide is an important new feature. The term 'climacteric rise' was employed by Kidd and West (1930) to denote the rise in respiration rate which marked the onset of ripening and senescence in Bramley's Seedling apples. It has since been adopted by many plant physiologists to denote similar phenomena in other fruits. In most fruits the beginning of the climacteric rise coincides with the first appearance of ripening colour, but this rule is not without exceptions. Granny Smith apples removed from store generally colour with no accompanying rise in respiration rate. Respiratory peaks may occur naturally, or be induced artificially, for a number of different reasons (e.g., artificial increase in oxygen supply). Many fruits have more than one respiratory peak (natural, or artificially induced) during the period of observation. For instance, three peaks occurred in sample 1, 1943, the first occurring in air twelve days after removal from store, the second and third being induced in pure oxygen eight and fourteen weeks, respectively, after removal from store. The causes underlying these peaks were different, and the onset of colouring was not associated with any of them. Thus care must be taken to guard against the indiscriminate use of the term 'climacteric rise' to denote peaks due to entirely different causes.

No explanation is at present available for the difference in the respiratory quotient of the 1943 Granny Smith apples before and after the respiratory peak. The respiratory quotient was frequently less than 1 on the first day after removal of the fruits from store but had risen to approximately 1 when the peak was observed. The reason for the low initial value is not known. When a fruit is removed from a low temperature to a higher one, various physical and chemical changes occur suddenly, and a number of hours must elapse before the equilibrium state for the new temperature is reached. Blackman and Parija (1928) studied the respiratory behaviour of Bramley's Seedling apples on removal from 2.5°C. to 22°C. It was found that the rate of output of carbon dioxide rose to a peak soon after the change was made; it then fell and seemed to have reached its new equilibrium 20 hours after being placed at 22°C. It is possible that the Granny Smith apples used in 1943 had not reached their new respiratory equilibrium when the first observation was made 25 hours after removal from store. If this was so, it is difficult to understand why the first reading was lower than, not higher than, later readings. All the physical changes usually thought to be associated with increases in temperature of the fruit (e.g., liberation of dissolved or adsorbed carbon dioxide) should tend to increase the rate of output of carbon dioxide rather than to decrease it.

Whatever the cause of the low initial respiratory quotient, it is improbable that the peak observed in the rate of output of carbon dioxide was solely due to the temperature change at the time of removal from store, since no such peaks were observed in the early samples for 1941, when the temperature changes were the same. There was apparently some real physiological difference between the 1943 fruits and those of previous years.

*The Relationship of Respiration Rate to Oxygen Supply.*—The strong positive correlation observed between internal oxygen concentration (governed by the resistance of the skin to gaseous diffusion) and respiration rate, in samples removed from store early in the year, has been fully discussed for 1941-42 in a previous paper (Hackney, 1943). The same correlation was observed in those of the 1943 samples which had not been in store for more than three months. In immature fruits, where the resistance of the skin to gaseous diffusion was low, the rate of production of carbon dioxide was not

affected when the fruit was held in an atmosphere of pure oxygen; from which it may be concluded that oxygen supply was not limiting respiration rate in these fruits. When early samples of mature fruits were held in an atmosphere of pure oxygen, the rates of production of carbon dioxide increased markedly, even in fruits which had been out of store for many weeks, and whose appearance and flavour suggested that they might have been poor in substrate. This fact, together with the positive correlation observed between internal oxygen concentration and respiration rate in the early mature samples, provides strong support for the theory that oxygen supply limits the respiration rate of the fruit during the greater part of its storage life. When the very late samples (late Nov.-Dec.) were held in pure oxygen, the respiration rate showed little or no change. It was suspected from the 1941-42 data that oxygen supply ceased to be the main factor limiting respiration rate late in the year. In late samples for 1941-42 the internal oxygen concentration rose as respiration rate declined, the resistance of the skin to gaseous diffusion remaining constant. In corresponding samples for 1943 the internal oxygen concentration did not rise as respiration decreased. This was due to the fact that the resistance of the skin to the diffusion of oxygen continued to increase.

The data obtained during 1943 lend strong support to the theory suggested by the data of 1941-42, namely, that oxygen supply is the main factor limiting respiration rate during the greater part of the storage life of the Granny Smith apple. The depressant effect of artificial lowering of the oxygen supply on respiration has been studied by several investigators, from Parija (1928) to Platenius (1943), but the possibility of the respiration rate being limited by natural restriction of oxygen supply is a comparatively recent discovery (Wardlaw and Leonard, 1936). The part played by oxygen supply in the Granny Smith apple may be summarized thus. In the immature fruits, where the resistance of the skin to gaseous diffusion is low, increased oxygen supply has no effect on respiration rate. At this stage, respiration rate is limited by some other factor, such as substrate supply or enzyme activity. In mature fruits which have not been in store for more than three or four months the rate of respiration is probably limited by oxygen supply. It is not directly limited by substrate scarcity or by lack of enzyme capacity, since increased oxygen supply results in an increased rate of respiration. In mature fruits which have been in store for six months or more, oxygen supply has probably ceased to be the main limiting factor. Respiration rate is then limited by some other factor, possibly the substrate scarcity suggested by Blackman and Parija (1928), possibly the deterioration of the enzyme system with advancing age of the fruit.

#### SUMMARY.

Two series of experiments have been carried out on the respiratory behaviour of Granny Smith apples of the 1943 season at 18.3°C. For the first series, the fruits were picked at various stages of development, and observations were made on respiration rates and composition of the internal atmosphere during the first two weeks after picking. For the second series, fruits of commercial maturity were stored at 0°C. Samples were taken from store at fortnightly intervals, and observations were made on respiration rates and composition of the internal atmosphere for at least four weeks. The effects of an atmosphere of pure oxygen on the respiration rate have been studied.

In immature fruits the initial respiration rates per unit weight decreased as development proceeded, until about six weeks before the date of commercial picking. When respiration rates were calculated in units per fruit, instead of per unit weight, this decrease was not evident. The respiration rates for individual fruits generally decreased throughout the period of observation. The respiratory quotient was approximately 1 throughout development. The internal oxygen concentration fell slightly and the internal carbon dioxide concentration rose slightly as development proceeded. The calculated resistances of the skin to the diffusion of oxygen and carbon dioxide increased slightly during development.

The behaviour of mature fruits which had not been in store for more than four months differed from that of fruits which had been in store for longer periods. In early samples the mean respiration rate (carbon dioxide output) generally rose to a peak soon after removal from store. After the peak was attained, the respiration rate

decreased throughout the period of observation. The decreasing respiration rate was associated with a decreasing internal oxygen concentration and an increasing resistance of the skin to the diffusion of oxygen. The respiratory quotient was frequently less than 1 on the day after removal from store but had risen to 1 two days later.

In the samples which had been in store until late in the year respiratory peaks did not occur, the respiration rates decreasing throughout the period of observation. The internal oxygen concentration was low on removal from store, and little change occurred subsequently. The resistance of the skin to the diffusion of oxygen was high initially and generally increased at 18.3°C.

Results of experiments in which apples were held in pure oxygen indicate that oxygen supply limits the respiration rate of mature apples which have not been in store for more than four months, but does not limit the respiration rate of either immature apples or apples which have been in store for more than four months.

The implications of these results are discussed in detail.

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## STUDIES IN THE METABOLISM OF APPLES.

## V. THE RESPIRATORY METABOLISM OF DELICIOUS APPLES OF COMMERCIAL MATURITY AFTER VARIOUS PERIODS OF COOL STORAGE.

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(Six Text-figures.)

[Read 26th July, 1944.]

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*Introduction.*

Previous papers in this series (Hackney, 1943*a*, 1943*b*, 1944) are concerned with the respiratory metabolism of Granny Smith apples after various periods of cool storage. It was shown that in Granny Smith apples which had not been in store for more than three or four months internal oxygen supply plays a very important part in the limitation of the respiratory activity. Evidence already collected indicates that the changes in internal oxygen concentration are affected by such factors as number of lenticels and their degree of openness, and the amount of oil developed on the skin. The present investigations were undertaken on Delicious apples in order to compare their metabolism with that of Granny Smith apples. Delicious apples differ from Granny Smith apples in that their skins generally do not develop very much oil. There are also important anatomical differences between the two varieties.

The present paper embodies the results of investigations on the post-storage metabolism of Delicious apples of commercial maturity in the 1942 and 1943 seasons. The rôle of oxygen in the metabolism of Delicious apples is very different from that taken in the metabolism of Granny Smith apples, and it will be shown that the difference is probably related to the difference between the fruits in their permeability to gaseous diffusion.

MATERIALS AND METHODS.

The fruits for the 1942 experiments were part of the normal commercial picking from Batlow, N.S.W. They were picked on 25.iii.42 and placed in cool store at Batlow until 20.v.42. They were then despatched to Sydney, where they were placed again in cool store (0°C.) one day later (21.v.42). At intervals of two weeks from 26.v.42, samples of five fruits each were withdrawn from store and taken to a room at a constant temperature of 21°C. For each apple in the sample, the rate of output of carbon dioxide and the composition of the internal atmosphere were measured at regular intervals, the measurements being continued in most samples until the fruits showed signs of advanced senescence.

Rates of output of carbon dioxide were measured by the Pettenkofer method and expressed in milligrams of carbon dioxide per 10 Kilograms fresh weight per hour. Concentrations of oxygen and carbon dioxide in the internal atmosphere were measured, using the method described in the first paper of this series (Trout *et al.*, 1942).

The fruits for the 1943 experiments were picked at Orange, N.S.W., on 15.iv.43. They were stored in Sydney at 0°C. on 19.iv.43. Samples of five fruits each were withdrawn from store at fortnightly intervals. The first sample was taken on 19.iv.43 and had not been in cool store. The subsequent behaviour of all the samples was observed at 18.3°C.,

no room at 21°C. being available. Measurements were made of the rates of uptake of oxygen and output of carbon dioxide and of the concentrations of these gases in the internal atmosphere.

The Pettenkofer method was not used in 1943. The rates of uptake of oxygen and output of carbon dioxide were measured by the method described by Sykes (1944).

Shortly after investigations were begun in 1942 on Delicious apples, it was discovered that about 75% of the fruits had open calices—a feature almost completely absent from Granny Smith apples. The condition of the calyx was ascertained as follows: The fruit, fitted with a gas-sampling pipette,\* was immersed in water, the end of the pipette being held in air. The pipette was then opened temporarily while air was blown gently through the fruit. Bubbles appeared through the calyx if it was open. While carrying out this test it was discovered that the lenticels of Delicious apples are very frequently open. Those of Granny Smith apples are generally closed. As the investigations were planned in order to compare the metabolism of two varieties (Granny Smith and Delicious) having different types of skin, it was thought best in 1942 to seal the open calices with wax and so limit gaseous diffusion to the skin.

During 1943, the calices were sealed in samples 1 and 2, but in later samples they were left untreated. The degree of closure was ascertained by the air bubble technique used in 1942. If no bubbles appeared when air was blown into it, the fruit was classified as 'closed'; if few bubbles appeared, it was classified as 'half-open'; if a rapid stream of bubbles appeared, it was classified as 'open'. When being analysed, the results were grouped according to these three categories.

#### EXPERIMENTAL RESULTS. A—1942 SEASON.

Table 1 shows date of removal from store, date of insertion of gas-sampling pipette, date of first observation, date of final observation and number of weeks in cool store for each of the twelve samples taken during 1942.

TABLE 1.

*Delicious Apples of the 1942 Season; Picked 25.iii.42; Cool-stored at 0°C. on 27.iii.42.*

Sample Number.	Date of Removal from Store.	Date of Insertion of Sampling Pipette.	Date of First Observation.	Date of Final Observation.	Number of Weeks in Cool Store.
1	26.v	26.v	27-28.v	27-29.vi	9
2	8.vi	9.vi	10-11.vi	23-24.vii	11
3	22.vi	23.vi	24-25.vi	17-18.viii	13
4	7.vii	8.vii	9-10.vii	11-12.viii	15
5	20.vii	21.vii	22-23.vii	22-24.viii	17
6	3.viii	4.viii	5- 6.viii	1- 2.ix	19
7	19.viii	19.viii	20-21.viii	15-16.ix	21
8	2.ix	3.ix	4- 5.ix	4- 5.xi	23
9	22.ix	23.ix	24-25.ix	3- 4.xi	26
10	12.x	12.x	13-14.x	5- 6.xi	29
11	26.x	26.x	27-28.x	12-13.xi	31
12	10.xi	10.xi	11-12.xi	30.xi-1.xii	33

*Respiration Rates.*—Figure 1 shows mean rate of output of carbon dioxide for each of the twelve samples. Owing to technical difficulties readings were not obtained for sample 4 until fifteen days after removal from store. With the exception of those of sample 5, all the fruits of all the samples had very high rates of output of carbon dioxide during the first few days after removal from store. Considerable variability was observed between the respiration rates of individuals within each sample; therefore the standard deviation of each sample was very large. However, the shape of the respiration-time curve was the same for each fruit. In general, the mean respiration rate fell irregularly throughout the period of observation. The peak observed in sample 1 was

\* The pipette had been inserted in order to sample the internal atmosphere.

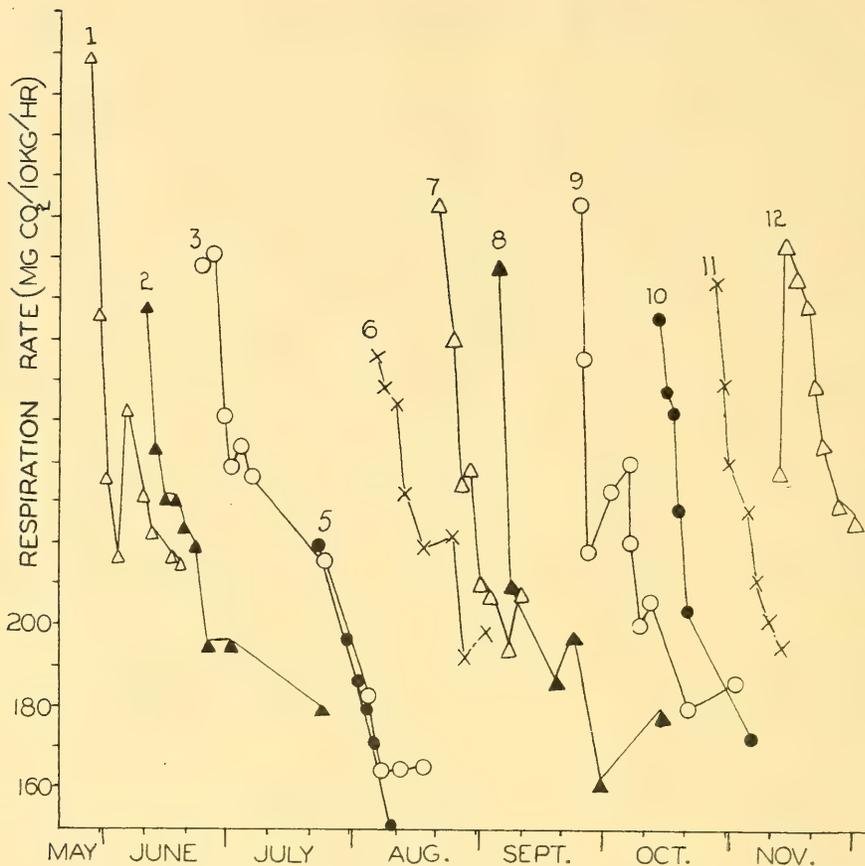


Fig. 1.—Mean rates of output of carbon dioxide for eleven of the twelve samples of Delicious apples taken during 1942. Values for sample 4 have been omitted to avoid confusion of the figure.

significant;\* it might have been due to the fact that the fruits were sealed only a few hours before the highest respiration rate was observed. The open calices were not noticed until 4.vi.42. The equilibrium between the gas concentrations inside and outside the fruits might not have been regained when the reading was taken. With the exception of sample 5, where the variability was unusually low, no differences were observed between the mean initial respiration rates of the various samples.

*Composition of the Internal Atmosphere.*—Figure 2 shows the mean concentrations of oxygen and carbon dioxide in the internal atmosphere for each sample taken during 1942. The calices of fruits in sample 1 were sealed after observations had been made on 5.vi.42. In the early samples (1 to 8 inclusive), the mean internal oxygen concentration fell throughout the period of observation, the lowest values being attained by samples 4, 5 and 6. Very little change was observed in the corresponding concentrations of carbon dioxide. The initial internal oxygen concentration showed a tendency to decrease from sample to sample until sample 5 was reached. After this no definite trend was observed. Sample 5 had the lowest internal oxygen concentration. In the late samples (9 to 12 inclusive), the internal oxygen concentration was comparatively high

\* The peak observed in sample 1 was significant because it occurred in every individual fruit of the sample. The peak observed in the mean respiration rate of sample 12 was not significant since the values for some fruits of this sample remained low while those for the other fruits rose, i.e., the standard deviation was high at this point of the curve.

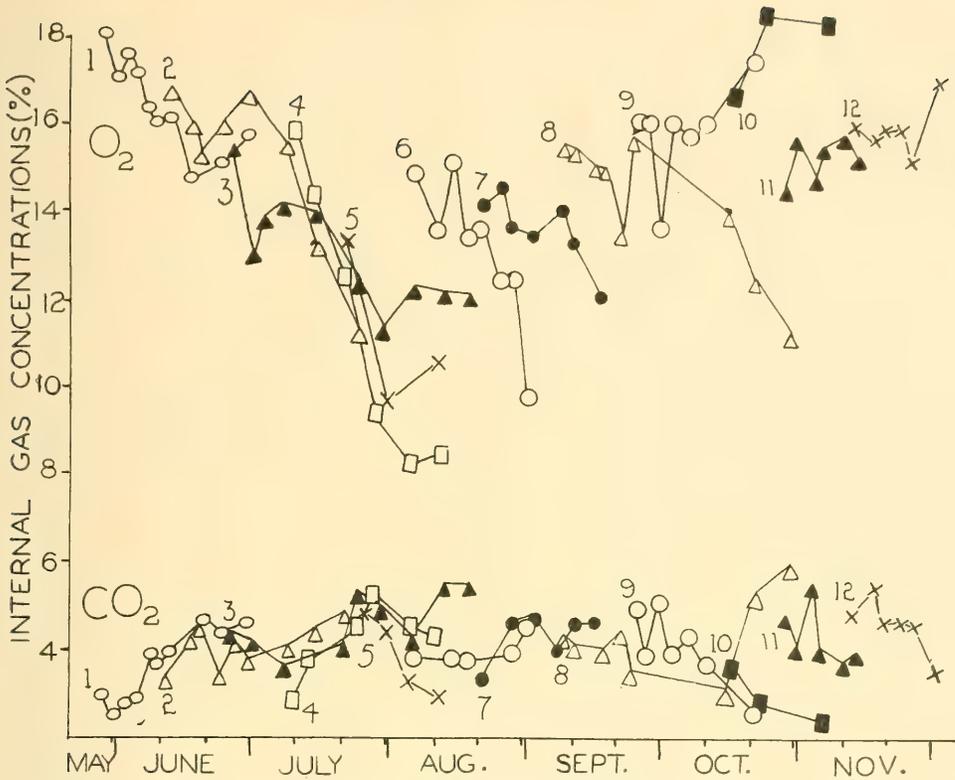


Fig. 2.—Mean concentrations of oxygen and carbon dioxide in the internal atmospheres of the twelve samples of Delicious apples taken during 1942.

initially and either remained constant or rose slightly. The corresponding concentrations of carbon dioxide generally fell throughout the period of observation.

*Resistance of the Skin to Gaseous Diffusion.*—The resistances of the skin to the diffusion of oxygen ( $r_o$ ) and carbon dioxide ( $r_c$ ) were calculated by the method outlined in the first paper of this series (Trout *et al.*, 1942). The mean values for the various samples are shown in Figure 3. In samples 1 to 7,  $r_o$  increased throughout the period of

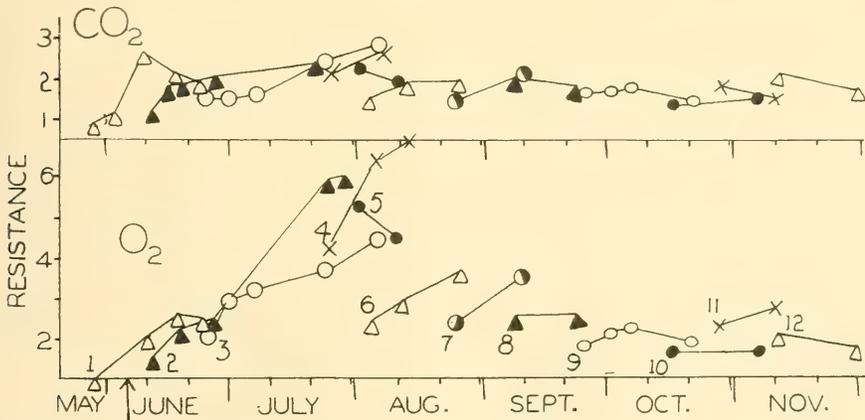


Fig. 3.—Mean resistances to the diffusion of oxygen and carbon dioxide for each of the twelve samples of Delicious apples taken during 1942. The arrow indicates date of closure of the open calices.

observation, the increase being most marked in samples 1 to 4 (over 4 units in 40 days in sample 2). In samples 8 to 11 inclusive,  $r_o$  remained constant throughout the period of observation. The initial values for  $r_o$  increased from sample to sample until sample 5 was reached. This sample had the highest initial value for  $r_o$ . The initial values for  $r_o$  were comparatively low in samples 6 to 12 inclusive.

The value for  $r_c$  showed very little change throughout the year.

#### EXPERIMENTAL RESULTS. B—1943 SEASON.

Table 2 shows date of removal from store and insertion of gas-sampling pipette (same day), date of first observation, date of final observation and number of weeks in cool store for each of the sixteen samples taken.

TABLE 2.  
*Delicious Apples Picked 15.iv.43; Cool-stored (0° C.) on 19.iv.43.*

Sample Number.	Date of Removal from Store.	Date of First Observation.	Date of Final Observation.	Number of Weeks in Cool Store.
1	19.iv	20.iv	18.v	0
2	4.v	5.v	11.vi	2
3	18.v	19.v	13.vii	4
4	1.vi	2.vi	4.viii	6
5	15.vi	16.vi	30.vii	8
6	6.vii	7.vii	17.viii	11
7	20.vii	21.vii	10.ix	13
8	2.viii	3.viii	2.ix	15
9	18.viii	20.viii	8.ix	17
10	31.viii	1.ix	21.x	19
11	15.ix	16.ix	21.x	21
12	5.x	6.x	18.x	24
13	19.x	20.x	11.xi	26
14	2.xi	3.xi	23.xi	28
15	16.xi	17.xi	1.xii	30
16	7.xii	8.xii	13.xii	33

*Respiration Rates.*—For the preliminary analysis of the data, the fruits were grouped in three anatomical classes—those with closed calices, those with moderately open calices and those with very open calices. The rates of uptake of oxygen and output of carbon dioxide were then considered separately for each apple in each group. Great variability was observed between individual fruits of the same type in the same sample, and no significant differences were observed between individual fruits of the same type in different samples or between those of different types in the same sample. In view of these facts, mean values have been calculated for all the fruits of each sample, and these are given in Figure 4. The values for some of the samples have been omitted in order to make the figure clear. Nothing essential is lost by doing this, as the samples omitted behaved similarly to those included. The rates of uptake of oxygen and output of carbon dioxide usually fell irregularly throughout the period of observation, but slight significant peaks (see footnote, p. 110) were observed in the rates of output of carbon dioxide in samples 4, 5, 6 and 7 soon after removal from store. Similar peaks were also observed in occasional individual fruits of other samples. Their occurrence was not limited to apples of any anatomical class. The mean initial rates of uptake of oxygen and output of carbon dioxide showed no significant trends from sample to sample. The rates of fall in respiratory activity were approximately the same for all the samples.

*The Respiratory Quotient.*—Mean values for respiratory quotients of the sixteen samples are shown in Figure 4. Only the first few values obtained are included in the figure as no change occurred subsequently. As in Granny Smith apples of the 1943 season (Hackney, 1944), some of the samples had respiratory quotients of less than 1 on the day after removal from store. The respiratory quotient had generally risen to approximately 1 when the second observation was made. It remained at this level during the remainder of the period of observation. There is no reason to suppose that the first observation

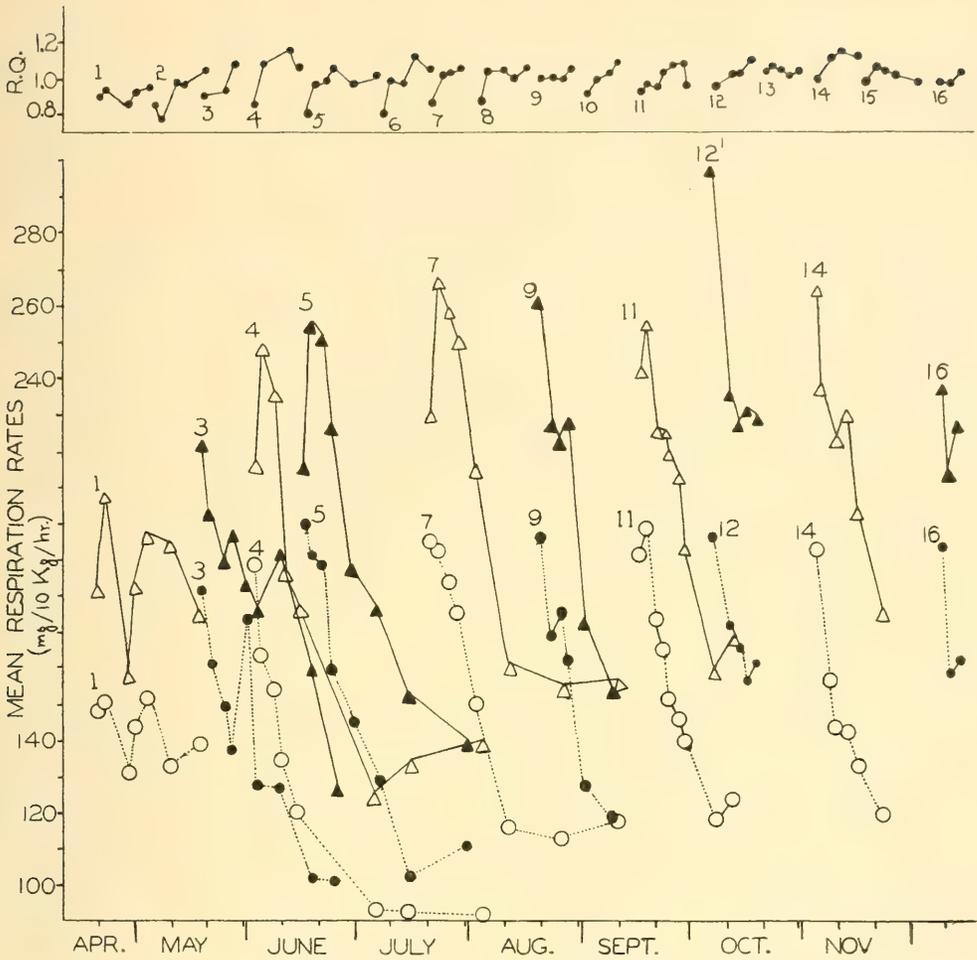


Fig. 4.—Mean values for respiratory quotient (R.Q.) for all the samples, and mean respiration rates for ten of the sixteen samples of Delicious apples taken during 1943. The samples omitted behaved similarly to those included. Values for rate of uptake of oxygen are joined by dotted lines; those for rate of output of carbon dioxide are joined by entire lines.

after removal from store was more subject to technical inaccuracies than subsequent observations (see Hackney, 1944).

*Composition of the Internal Atmosphere.*—For the comparison of the compositions of the internal atmospheres the fruits were grouped in three anatomical classes, according to the structure of the calyx. Figure 5*a* shows the internal concentrations of oxygen in the fruits which had open calices (means for each sample). The mean internal concentrations of carbon dioxide in these fruits were low (about 3% or less). During the period of observation at 18.3°C. very little change occurred in the composition of the internal atmospheres of these fruits. Further, the composition of the internal atmosphere on removal from store was the same at the end of the year as at the beginning. The internal atmospheres of fruits with moderately open calices were similar in composition to those of fruits with very open calices. When, however, the mean internal oxygen concentrations for all the fruits with closed calices were compared with those for fruits with open calices, the differences were statistically significant ( $P < 0.001$ ). When the behaviour of individual fruits was considered, it was found that fruits with closed calices varied in the composition of their internal atmospheres. In

some fruits of this type the internal atmospheres were not significantly different from those of fruits with open calices. In other fruits the internal oxygen concentration was either initially low or fell during the period of observation until it reached a level considerably lower than the lowest level observed in any fruit with an open calyx.

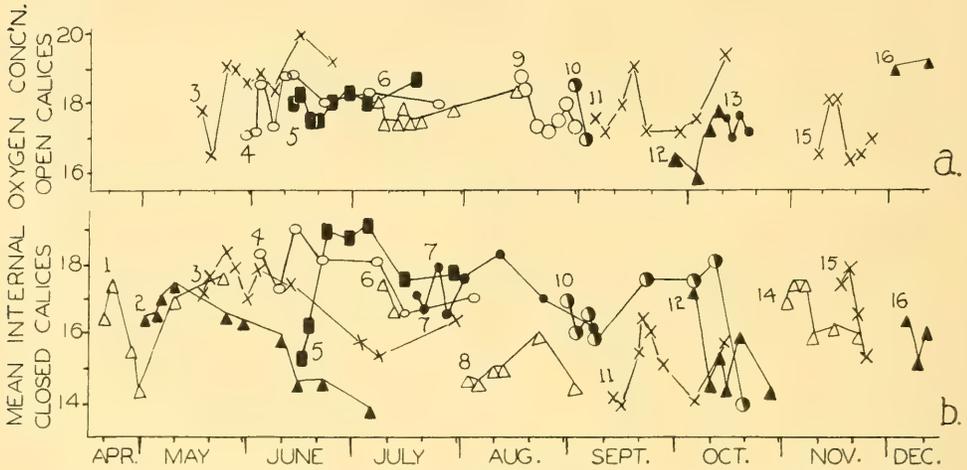


Fig. 5.—Mean internal oxygen concentrations for (a) fruits with open calices, (b) fruits with closed calices. The fruits were those of the 1943 season, and the numbers on the curves indicate the samples from which they were taken.

Figure 5b shows the mean internal oxygen concentrations of the fruits with closed calices. No significant difference was observed between the mean concentrations of carbon dioxide in the internal atmospheres of fruits of the three anatomical classes.

*Resistance to Gaseous Diffusion.*—In fruits with open calices the values for resistance to the diffusion of oxygen were low, and very little change was observed throughout the period of observation. Figure 6 shows the corresponding values for fruits with closed calices. In some of these fruits no appreciable change was observed during the period of observation. In others the resistance to the diffusion of oxygen rose considerably after removal from store. A striking example of variability is pre-

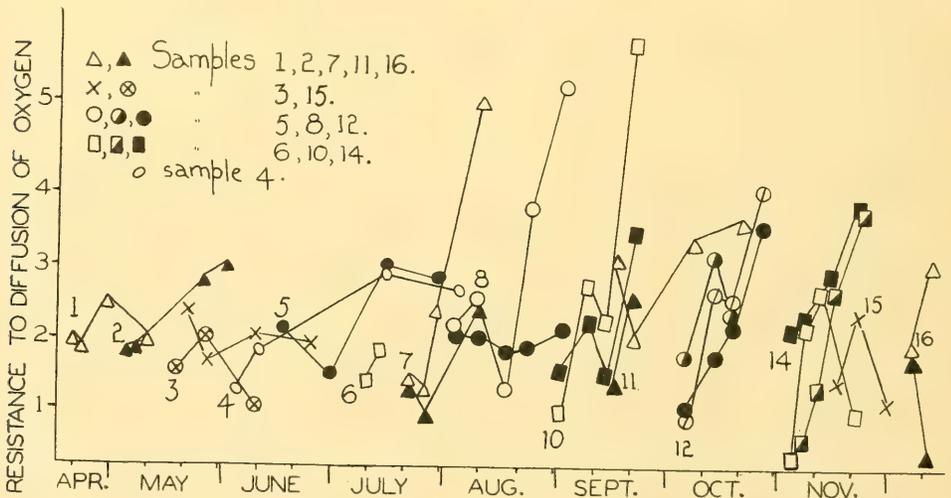


Fig. 6.—Values for resistance to diffusion of oxygen for individual fruits which had closed calices in 1943. The numbers on the curves indicate the samples from which these fruits were taken; each fruit is represented by a different symbol.

sented by the two 'closed' fruits of sample 8. The oxygen resistance of one of these remained constant throughout, while that of the other rose steeply.

In most fruits the resistance to the diffusion of carbon dioxide did not change appreciably, but it increased considerably in a few fruits which had closed calices (e.g., in sample 12, original values for three fruits were 1.1, 1.2 and 1.2 units, respectively, and final values were 4.1, 3.6 and 2.4, respectively).

#### DISCUSSION OF RESULTS.

##### A. COMPARISON OF RESULTS FOR 1942 AND 1943.

*Respiration Rates.*—In many respects the respiration records of the 1943 fruits are similar to those of the 1942 fruits. In both seasons the mean rates of output of carbon dioxide for any particular sample on successive occasions generally fell throughout the period of observation. Some of the 1943 samples showed slight respiratory peaks, the occurrence of which could not be correlated with any particular characteristic of the fruit. No definite trends were observed among the initial respiration rates of successive samples in either season. The general level of the respiration rate was higher in 1942 than in 1943, probably because the fruits were held at a higher temperature (21°C.) during 1942.

In 1942, alcohol analyses were carried out on fruits which had been in store for various periods. The analyses were carried out about six days after removal from store and it was found that the fruits contained between 0.02% and 0.05% of alcohol. In 1943, it was found that the respiratory quotient was approximately 1 when the fruit had been out of store for three days or longer. If any anaerobic respiration was going on, the amount of carbon dioxide produced in this way was apparently too small to change the respiratory quotient noticeably.

*Composition of the Internal Atmosphere.*—Changes in the composition of the internal atmosphere with time were much more marked in 1942 than in 1943. Two factors probably contributed to this difference. In 1942 all the fruits had closed calices, those which were naturally open being sealed with wax, whereas in 1943 this was not so. Thus the population was more homogeneous in 1942 than in 1943. In addition, the experimental temperature was nearly three Centigrade degrees higher in 1942. As a general rule, any changes in the internal atmosphere of an apple occur more quickly and are more pronounced at higher than at lower temperatures. In 1942 the samples fell into two classes: those which had been in store for less than six months and those which had been in store longer. In the former class the internal oxygen concentrations of all the fruits fell throughout the period of observation, the lowest mean value observed being 8.3%. In the latter class the internal oxygen concentrations remained approximately constant. In 1943 the mean behaviour of all the samples was the same. In fruits which had open calices the internal oxygen concentration was high (about 18–19%) and the concentration of carbon dioxide was low (about 2–3%). In fruits with closed calices the extent of the changes in the composition of the internal atmosphere varied considerably. In some fruits the internal concentration of oxygen was high (about 18%) and did not change during the period of observation. In others the internal oxygen concentration was high initially and fell slowly at 18.3°C. In the remaining fruits the internal oxygen concentration was low initially (lowest observed being 10.8%) and either rose or remained constant subsequently. Thus in 1943 the group which most closely compared with the fruits of 1942 (i.e., the closed calyx type) showed considerably more variability within samples than did the 1942 fruits. It was observed that whereas in 1942 the earlier samples (1 to 8 inclusive) became very greasy after removal from store, the development of grease was not so great in the 1943 samples. Experience indicates that this difference may be due to the higher experimental temperature in 1942. In 1943 the lenticels were more open in some fruits than in others. Those with very open lenticels always had high internal oxygen concentrations. In 1942 the lenticels were open but did not appear to be as widely open as those of some of the 1943 fruits.

*Resistance to Gaseous Diffusion.*—Changes in the resistance to gaseous diffusion were more marked in 1942 than in 1943. In the early samples of the 1942 season, which were greasy, the resistance to the diffusion of oxygen ( $r_o$ ) increased throughout the period of observation. The initial values for  $r_o$  were low (about 2 units) and subsequent changes were small or negligible. Later samples were not noticeably greasy. In addition to the normal samples 8 and 9 (1942), in which the calices were waxed, two extra samples were taken from store on the same days as samples 8 and 9, respectively. The calices of these fruits were left open. There was no difference between these samples and samples 8 and 9 in respiration rate, composition of the internal atmosphere, or changes in  $r_o$  and  $r_c$ . In the early 1942 samples, where the value for  $r_o$  was high, any leaks which developed in the wax seals caused the internal oxygen concentration to rise noticeably. It would seem that in 1942 the resistance of the skin of the late samples was so low that the closure of the calyx made little difference.

In the 1943 samples, the resistance was always low (1 to 3 units) in fruits with open calices. In fruits with closed calices the values for  $r_o$  and  $r_c$  were sometimes so low as to be equal to those for fruits with open calices. In the majority of fruits with closed calices the value for  $r_o$  rose during the period of observation. As in the late samples in 1942, resistance of the skin was occasionally so low that the closure of the calyx made no noticeable difference.

#### B. GENERAL DISCUSSION.

*Respiration Rates.*—With the exception of the slight initial peaks observed in some of the early 1943 samples, there was no suggestion of any rise in respiration rate accompanying the onset of ripening. In 1942 the early samples were fairly ripe when removed from store, but in 1943 they were still flavourless. Fisher (1943) found that in Delicious apples at 60°F. (15.5°C.) respiration rate reached its peak about five days after picking. As the fruits considered in this paper were not put into store until several days after picking, possibly the respiratory peak was missed. Whether the slight peaks observed in the rates of output of carbon dioxide in samples 4, 5, 6 and 7 in 1943 were analogous to the climacteric peaks of Blackman and Parija (1928) and other workers or not, no peaks were observed in the corresponding curves for rate of uptake of oxygen; it is probable that most of the fruits of the 1943 season passed from the unripe to the fully senescent stage without showing any evidence of an increase in respiratory activity, measured either as uptake of oxygen or output of carbon dioxide. This probability, together with the fact that the Granny Smith apple has frequently been observed to ripen without any associated rise in the rate of respiration (Hackney, 1943), suggest that the 'climacteric peak' is not nearly as common an accompaniment of the onset of ripening as was once supposed.

In several of the 1943 samples the respiratory quotient, though approximately 1 for the greater part of the storage life, was significantly less than 1 on the day after removal from store. The reason for this is not known. The possible reasons for the similar phenomenon in Granny Smith apples have been discussed in the previous paper (Hackney, 1944).

*Resistance of the Skin to Gaseous Diffusion, and Composition of the Internal Atmosphere.*—In spite of the variations in resistance to gaseous diffusion, certain principles of behaviour appear to have been common to fruits of 1942 and 1943. The extent to which changes in the resistance of the skin affect the composition of the internal atmosphere depends on the extent of closure of the calyx. If the calyx is open no changes occurring naturally in the resistance of the skin impose sufficient restriction on the rate of gaseous diffusion to cause any noticeable change in the composition of the internal atmosphere. If the calyx is completely or almost completely closed, changes in the resistance of the skin tend to modify the composition of the internal atmosphere. In some of the closed fruits no noticeable changes occur in the resistance of the skin. It has been observed that these fruits frequently have very open lenticels, as measured by the pressure required to blow air through them. During 1943, the value for  $r_o$

increased throughout the period of observation when the calyx was closed. The increase in  $r_o$  was generally accompanied by a corresponding increase in  $r_c$ .

It appears that there is no invariable correspondence between the degree of closure of the calyx and the composition of the internal atmosphere. Late in 1943, four fruits were selected in which the calices were completely closed. Observations were made on rates of uptake of oxygen and output of carbon dioxide and composition of the internal atmosphere while the calices were closed. The calices were then opened with a sterilized needle and a similar set of observations was made 24 hours later. The concentrations of oxygen and carbon dioxide in the internal atmospheres before and after the opening of the calices are shown in Table 3. Corresponding values for  $r_o$  and  $r_c$  were calculated, assuming that the respiration rates of the fruits were approximately the same before and after the opening of the calices. In the two fruits (numbers 1 and 3 in Table 3), which had the highest values for  $r_o$  and  $r_c$  (about 2.0 and 1.6 units, respectively), the opening of the calices resulted in a noticeable reduction of both values (2.0  $\rightarrow$  1.1 units; 1.6  $\rightarrow$  1.0 units). In the other two fruits, where the initial resistances were slightly lower ( $r_o$  = about 1.4 units;  $r_c$  = about 1.3 units), the differences consequent upon the opening of the calices were so slight as to be insignificant; that this might have been due to the openness of the lenticels is shown by a second experiment (see below).

TABLE 3.

*Composition of the Internal Atmosphere before and after Artificial Opening of the Calices of Delicious Apples in December, 1943.*

Fruit No.	Date.	Condition of Calyx.	Internal O <sub>2</sub> (%)	Internal CO <sub>2</sub> (%)
1	30.xii.43	Naturally closed.	16.9	2.9
2	"	" "	18.7	2.1
3	"	" "	16.9	3.2
4	"	" "	17.7	2.9
1	31.xii.43	Artificially opened.	18.7	2.0
2	"	" "	18.9	1.8
3	"	" "	19.2	2.1
4	"	" "	18.0	2.6

In June, 1944, six Delicious apples were selected having closed calices and very open lenticels. They were placed in a room maintained at a constant temperature (21°C.). The concentrations of oxygen and carbon dioxide in the internal atmospheres were determined on 26.vi.44. The lenticels of three of the fruits were then painted with a solution of castor oil and shellac in alcohol, one of the preparations which are known to increase resistance to the diffusion of oxygen when applied to the skin (see Hackney, 1943*b*). The concentrations of oxygen and carbon dioxide in the internal atmospheres were again measured on 13.vii.44. The internal oxygen concentrations had decreased considerably in the fruits whose lenticels had been painted; in the untreated fruits the changes were small or negligible (Table 4).

It appears that in some fruits with closed calices the resistance of the skin is so low (probably due to the openness of the lenticels) that the composition of the internal atmosphere is not noticeably different from that in fruits with open calices.

*Comparison between Granny Smith and Delicious Varieties.*—When the data presented in this paper are compared with those previously presented for **Granny Smith** apples (Hackney, 1943*a*, 1943*b*, 1944) it is obvious that there are differences in behaviour between the two varieties. Mature Delicious apples have much higher respiration rates than Granny Smith apples under the same conditions. Changes in the composition of the internal atmosphere and in the resistance of the skin to gaseous diffusion are frequently less marked in the former variety than in the latter. When the preliminary investigations were being carried out on Granny Smith apples, several tests were carried out which proved that the resistance of the flesh of the fruit is very small compared with that of the skin (Trout *et al.*, 1942). Similar tests carried out on Delicious apples

TABLE 4.  
*Composition of the Internal Atmosphere before and after Artificial Closure of the Lenticels of Delicious Apples in June, 1944.*

Fruit No.	Date.	Condition of Lenticels.	Internal O <sub>2</sub> (%).	Internal CO <sub>2</sub> (%).
1	26.vi.44	Naturally open.	14.0	5.2
2	"	" "	14.8	5.1
3	"	" "	17.5	6.4
4	"	" "	16.6	6.0
5	"	" "	14.9	4.6
6	"	" "	16.5	4.0
J	"	" "	15.3	4.9
2	"	" "	17.9	4.2
3	"	" "	14.5	4.6
4	"	Artificially closed.	3.9	8.6
5	"	" "	8.4	5.9
6	"	" "	11.6	7.3

in 1943 showed that in this variety also the resistance of the flesh is very low. It appears, therefore, that the differences between the resistance changes observed in the two varieties are due to differences in the skin and in the structure of the calyx. The occurrence of the open calyx in the Delicious variety and its absence from the Granny Smith have already been mentioned. In addition, the development of oil on the surface of the fruit is often more noticeable in the Granny Smith than in the Delicious apple. Probably the most important difference between the skin of the Delicious apple and that of the Granny Smith is that of the lenticel structure. It has been shown by anatomical study (N. O'Grady, 1941\*) and by the air-bubble test described in this paper, that the lenticels of the Granny Smith apple are generally closed. In the Delicious apple they are generally open. It has been observed by the writer that, in the very few Granny Smith apples where the lenticels were open, there were considerably greater concentrations of oxygen in the internal atmospheres than in comparable apples where the lenticels were closed.

Data have been presented in previous papers (Hackney, 1943*a*, 1943*b*, 1944) to show that oxygen supply plays a very important part in the limitation of the respiration rate of Granny Smith apples during a certain period of their life. Strong positive correlations have been observed between internal oxygen concentration and respiration rate in Granny Smith apples which have not been in store longer than three or four months. The same apples have shown rapid acceleration of respiratory activity when held in pure oxygen. No data have been obtained regarding the behaviour of Delicious apples in pure oxygen. In the early samples of Delicious apples of the 1942 season, strong positive correlations ( $P < 0.01$ ) were observed between internal oxygen concentration and respiration rate, but in later samples of 1942, and in all the 1943 samples, no such correlations were observed. Respiration rate frequently fell while internal oxygen concentration remained constant. It appears that some factor other than oxygen supply limits the respiration rates of the majority of Delicious apples.

It is evident from the complexity of the results presented in this paper, and others of the same series, that investigations of the respiratory metabolism of fruits should include not only observations of the external respiration rates but detailed studies of the changes which may occur in the resistances of the fruits to gaseous diffusion. Without such studies it is impossible to decide whether changes in the respiratory intensity are due to limitation of the internal oxygen supply or to some other factor, such as substrate starvation or the deterioration of the enzyme system.

#### SUMMARY.

During 1942 and 1943, investigations have been carried out on Delicious apples of commercial maturity after various periods of storage at 1°C.

\* Unpublished data.

Observations have been made on rates of uptake of oxygen and output of carbon dioxide, respiratory quotients and composition of the internal atmosphere. The resistances of the fruit to the diffusion of oxygen and carbon dioxide have been calculated from the data obtained.

It was found that the Delicious apple frequently has an open calyx. In an attempt to ensure uniformity, the open calices were sealed with wax in 1942; during 1943 the calices were left untreated, and the data have been analysed in three classes according to the degree of closure of the calices.

The rates of uptake of oxygen and output of carbon dioxide generally fell throughout the period of observation. In 1943, slight peaks were observed in the rates of output of carbon dioxide in some samples shortly after removal from store. No corresponding peaks were observed in the rates of uptake of oxygen. No difference was observed between the respiration rates of apples with closed calices and those with open calices.

The respiratory quotient was frequently less than 1 on the first day after removal from store, but had risen to 1 on the third day after removal from store.

The degree of closure of the calyx had a small but statistically significant effect on the mean internal oxygen concentration. In fruits with open calices the internal oxygen concentration remained high. In fruits with closed calices it sometimes fell to a relatively low level.

In fruits with open calices the resistances of the fruit to the diffusion of oxygen and carbon dioxide did not rise during the period of observation. In those where the calyx was completely or almost completely closed, the resistances to the diffusion of oxygen and carbon dioxide frequently rose.

These results are discussed in detail, and are compared with those presented in previous papers for Granny Smith apples. Attention is drawn to the great differences between the rôles of oxygen in the metabolism of the two varieties. These differences are related to differences in the permeabilities of the two varieties to gaseous diffusion.

#### *Acknowledgements.*

The writer wishes to express her thanks to Professor E. Ashby, Department of Botany, University of Sydney, and to Dr. J. R. Vickery, Council for Scientific and Industrial Research, Homebush, for their advice and for the use of their laboratories and facilities; to Dr. S. A. Trout, Council for Scientific and Industrial Research, Homebush, and Dr. R. N. Robertson, Department of Botany, University of Sydney, for their guidance in the planning and carrying out of the investigations; and to Mr. E. W. Hicks, Council for Scientific and Industrial Research, Homebush, Mr. E. G. Hall, Department of Agriculture, N.S.W., Dr. F. E. Huelin and Mr. S. M. Sykes, Council for Scientific and Industrial Research, Homebush, for their advice and criticism.

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## CONTRIBUTIONS TO A KNOWLEDGE OF AUSTRALIAN CULICIDAE. No. VII.

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Medicine, University of Sydney.

(Nine Text-figures.)

[Read 30th August, 1944.]

The present paper represents some notes which were made several years ago concerning synonymy and which have been confirmed recently. I have also added illustrations of several species with but little or no explanatory letterpress, it being my opinion that a correctly drawn illustration, *provided that it is of such a magnification as to be of easy interpretation*, requires no, or very little, explanation.

The larva and pupa of *Taeniorhynchus (Coquillettidia) xanthogaster* Edwards are made known for the first time. I have borrowed, and herewith acknowledge, the description and illustrations of the larva of *Taeniorhynchus (Coquillettidia) crassipes* van der Wulp from Bonne-Wepster.

One species of *Finlaya* has been described and renamed due to the incorrect association of the sexes. It has been necessary to rename a previously described species, since the species name had been previously used.

## BIRONELLA (BRUGELLA) HOLLANDI Taylor.

PROC. LINN. SOC. N.S.W., lix, 1934, 229.

The terminalia and wing of this species have not previously been illustrated.

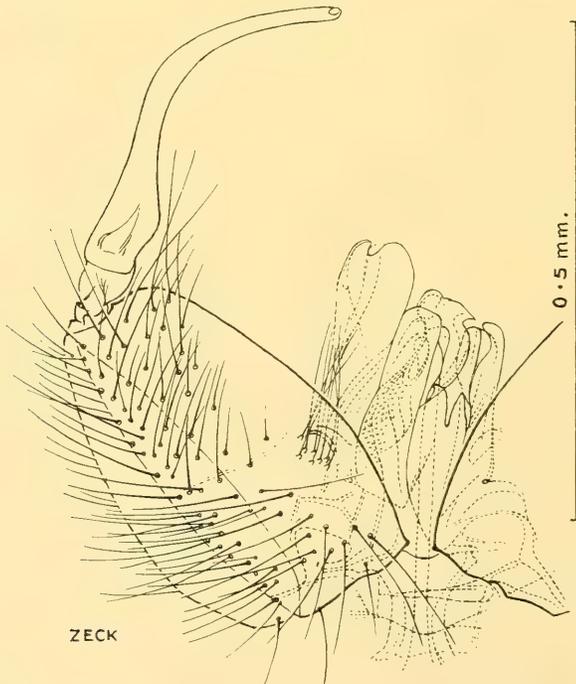


Fig. 1.—*Bironella (Brugella) hollandi* Taylor. ♂ terminalia.

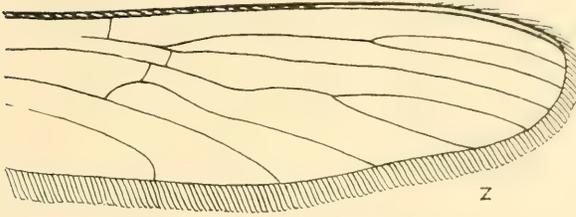


Fig. 2.—*Bironella (Brugella) hollandi* Taylor. Wing.

*AËDES (FINLAYA) ALBITARSIS* Taylor.

*Trans. Ent. Soc. Lond.*, 1913 (1914), 194 (*Leucomyia*); Edwards, *Bull. Ent. Res.*, xiv, 1924, 382 (*Finlaya palmarum*).

I was in error in describing the thoracic ornamentation as a median "line of white scales. . ." It is in fact a moderately broad *stripe*. The remaining differences are so slight that they do not matter. Edwards stated that the thoracic stripe in his type was composed of golden and not white scales. Even so, I see no reason for keeping the two 'species' names.

*Habitat*.—Queensland: Eungella *via* Mackay (F. H. Taylor); Berner Creek *via* Innisfail (F. H. Taylor).

The type specimen of *albitarsis* came from the Lakekamu Gold Field, Papua, that of *palmarum* from Palm Island, north of Townsville, Queensland.

*AËDES (FINLAYA) PULCHERRIMUS* Taylor.

*Proc. Linn. Soc. N.S.W.*, xliii, 1919, 830 (*Mimeteomyia*); Edwards, *Bull. Ent. Res.*, xiv, 1924, 382.

Some female *Finlaya* were associated with the male type of the above species in the Collection of the School of Public Health and Tropical Medicine, University of Sydney. The type, a male, is not a *Finlaya* nor even a valid species, being nothing more than an aberrant form of *Aëdes (Stegomyia) aegypti* L. By whom the female, a good species, was associated with the name, it is now impossible to say. Possibly Hill associated the sexes, since he found females at Townsville (*vide* Edwards above). Hill did not put these specimens in the collection when on the staff of the Australian Institute of Tropical Medicine, Townsville. Female specimens, which were taken at Eidsvold, Queensland, were presented to the Institute by the late T. L. Bancroft.

My attention was first called to the above confusion by Lieutenant-Colonel W. V. King, who was going over our collection. He remarked that the type of scales of the thoracic ornamentation was different in the sexes and had I noticed it? I told Colonel King that I had not examined the type since I described it, nor had I looked at the female specimens. I made a preparation of the terminalia of the type and found that, though somewhat aberrant, the specimen was nothing more than *Aëdes (Stegomyia) aegypti* L.

The female specimens from Eidsvold require a new name and are described below as *Aëdes (Finlaya) mallochi*, n. sp.

*AËDES (FINLAYA) MALLOCHI*, n. sp.

♀. Head covered with dusky brown flat scales and upright-forked black ones, a small patch of semi-erect fairly broad white ones basally in the centre, a row of small pure white broad ones bordering the eyes; palpi black scaled, white scaled at the base and apex; there is also a median white band; antennae dark brown, verticillate hairs dark brown, pubescence pale; proboscis dusky brown.

Thorax blackish covered with dull coppery narrow-curved scales adorned with lyre-shaped pattern of pure white small broad, flat scales, posterior arms of the lyre reaching the posterior border of the scutum, a median line of similar white scales extending from the anterior margin almost to the posterior margin, where there is a very short sloping white line on either side of the median; another line of similar scales extends from,

and includes, the pronotal lobes, curving upwards over the wing-roots to the posterior margin of the scutum; scutellum with posterior border covered with dense white flat scales; pleurae with two equally spaced oblique lines of white, small, flat scales, another arising about the middle of the upper oblique line and extending to below the posterior margin of the wing base.

Legs: Coxae with a pronounced line of white flat scales, trochanters white scaled, femora and tibiae with a conspicuous white line of scales laterally. Knee spots white; first, second and third tarsal segments of fore- and mid-legs with white basal banding, inconspicuous on the third, tarsal segments of hind-legs, one to four with conspicuous white basal banding, fifth all white.

Wings covered with chocolate-brown scales, bases of the first and second fork-cells level; *m-cu* about one and a half times its length from *r-m*. Length of wing 3.5 mm.

Abdomen covered with chocolate-brown scales, unbanded, segments with white lateral basal spots, first segment with the entire lateral margin white; venter apparently white scaled.

*Habitat*.—Queensland: Eidsvold (T. L. Bancroft); Townsville (G. F. Hill, *vide* Edwards).

This species may be separated from *Aedes (Finlaya) notoscriptus* (Skuse) by the white lines being composed of broad flat small scales, whereas in *notoscriptus* they are composed of narrow-curved ones. The proboscis is also entirely dark. Named after J. R. Malloch, whose contributions have materially advanced the study of Australian Diptera.

#### AÈDES (FINLAYA) PURPUREUS Theobald.

*Mon. Culicidae*, v, 1910, 479 (*Molpemyia*); Taylor, *Trans. Ent. Soc. Lond.*, 1913 (1914), 684 (*Calomyia priestleyi*); Edwards, *Bull. Ent. Res.*, xiii, 1922, 94 (*pecuniosus*); *op. cit.*, xiv, 1924, 380.

There are specimens, ♂, ♀, in the collection of this School from Derby, West Australia, bred from larvae taken from a rot hole in a tree by Dr. A. H. Baldwin and the late L. E. Cooling, a female taken by L. E. Cooling on Elcho Island, Northern Territory, male and female specimens bred from larvae found in a rot hole in a tree at Herberton by C. O'Brien and, finally, the type of *priestleyi*, a female specimen taken by Dr. H. Priestley at Townsville, Queensland.



Fig. 3.—*Aedes (Finlaya) purpureus* Theobald. ♂ terminalia.

Theobald's type was a female from Stannary Hills, Queensland. Edwards' type, a female, came from Darwin, Northern Territory.

Geographically the above material comes from related areas, Derby in the west and Townsville in the east being the left and right wings of the distribution.

I have thought from the time that the additional material became available to me in 1925, that the three names represented one and the same species. The ornamentation of the thorax and the leg markings vary somewhat, as is to be expected in species that show a high degree of ornamentation. Moreover, the male terminalia of specimens from Derby and Herberton show no differences.

Colonel W. V. King, who compared a male and female specimen from Derby with a male and female from Herberton, could find no tangible differences in the males. There is no question that *priestleyi* Taylor is the same as the Herberton specimens which are definitely *purpureus* Theobald. I can not conceive that the Elcho Island and Derby specimens are not *pecuniosus* Edwards. I have no hesitation in placing *priestleyi* Taylor, and *pecuniosus* Edwards as synonyms of *purpureus* Theobald. Responsibility for the synonymy is entirely mine.

AÈDES (AÈDES) CUNNINGHAMI, new name.

*bancrofti* Taylor (*nec* Skuse), Proc. LINN. Soc. N.S.W., xxxix, 1914, 465.

A change of name is necessary since *bancrofti* was used for *Culex bancrofti* Skuse, which is a synonym of *Aedes (Stegomyia) aegypti* Linn. Named after Allan Cunningham, the botanist, who spent some time in New South Wales.

TAENIORHYNCHUS (COQUILLETIDIA) GIBLINI Taylor.

*Trans. Ent. Soc. Lond.*, 1914, 198; Edwards, *Bull. Ent. Res.*, xiv, 1924, 365.

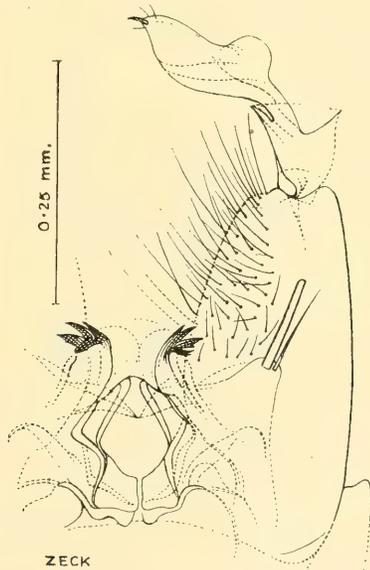
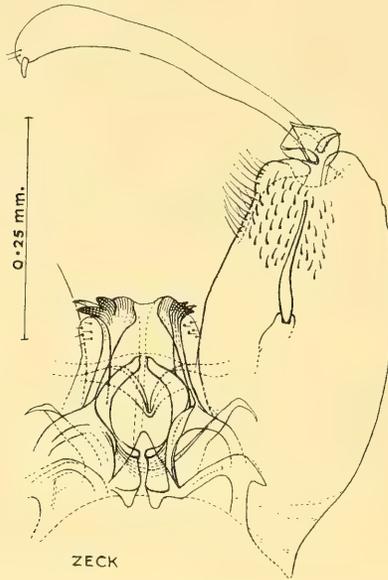
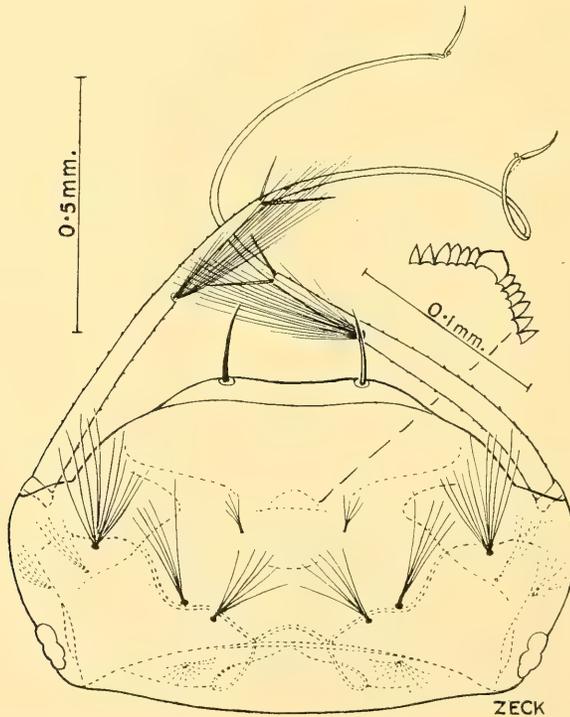


Fig. 4.—*Taeniorhynchus (Coquillettidia) giblini* Taylor. ♂ terminalia.

## TAENIORHYNCHUS (COQUILLETIDIA) XANTHOGASTER Edwards.

*Bull. Ent. Res.*, xiv, 1924, 366.Fig. 5.—*Taeniorhynchus (Coquillettidia) xanthogaster* Edwards. ♂ terminalia.Fig. 6a.—*Taeniorhynchus (Coquillettidia) xanthogaster* Edwards. Larva, head.

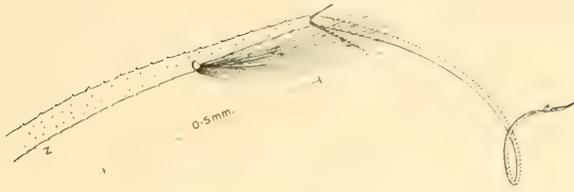


Fig. 6b.—*Taeniorhynchus (Coquillettidia) xanthogaster* Edwards.  
Larva, antenna enlarged.

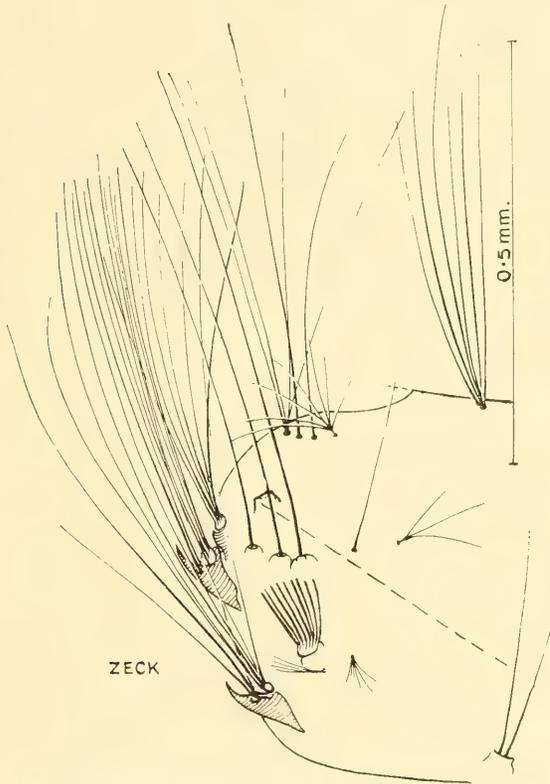


Fig. 6c.—*Taeniorhynchus (Coquillettidia) xanthogaster* Edwards. Larva, thorax.

Larva: Head with preclypeal spines stout, moderately long, dusky-brown. Antennae with antennal hair-tuft slightly above the base of the apical half of shaft, individual hairs, apparently simple, shaft dusky, becoming paler toward the hair-tuft, apical extension very long with a pointed spine-like apex. Hair A moderately long, well developed, with eleven branches, apparently simple, B slightly shorter than A and with five well-developed branches, apparently unbranched, C shorter than B with well-developed, apparently simple, branches, d about half the length of C with four simple branches.

Thoracic hairs as illustrated, the inner metapleurals (cut off in illustration) are all frayed.

Comb on the eighth segment composed of nine scales, form of scale as illustrated. The long bristle-like hair arising from below the comb distinctly frayed for about the apical half. Air-tube short, cone-shaped, the piercing apparatus saw-toothed on outer

edge, dark brown, the rest as illustrated. Anal segment slightly longer than air-tube, saddle almost completely covering it except for a narrow apical area, basal portion of saddle dark brown, heavily chitinized, dorsal edge with numerous small, fine teeth; anal papillae broken off.

The larva from which the above notes were made was taken some years ago from a small swamp covered with waterweeds of various kinds; the pupa was found at Cairns in a swamp almost entirely covered with cyperaceous plants.

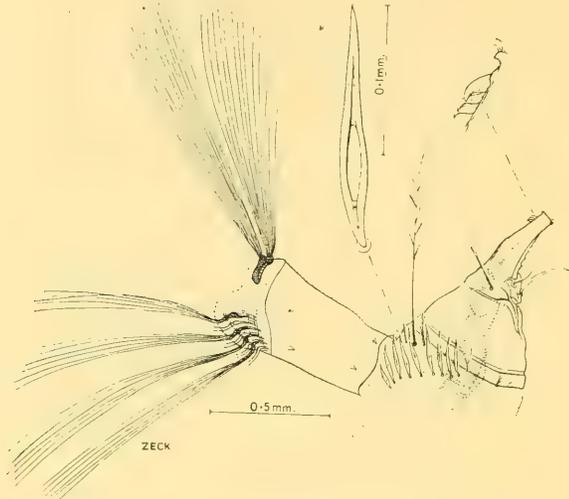


Fig. 6d.—*Taeniorhynchus* (*Coquillettia*) *xanthogaster* Edwards. Larva, apical segments.

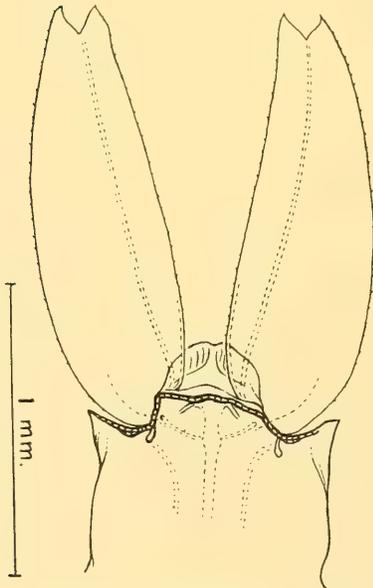


Fig. 7a.—*Taeniorhynchus* (*Coquillettia*) *xanthogaster* Edwards. Pupa, apex of abdomen.

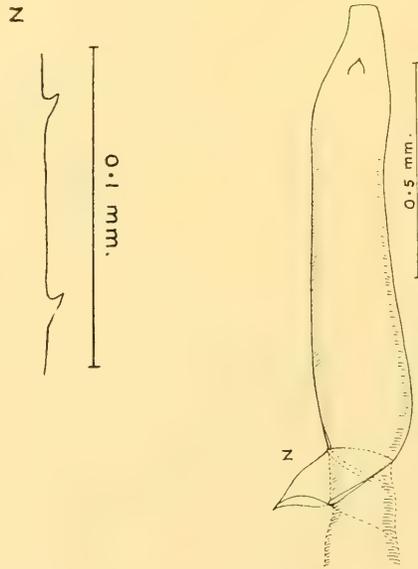


Fig. 7b.—*Taeniorhynchus* (*Coquillettia*) *xanthogaster* Edwards. Pupa, siphon.

TAENIORHYNCHUS (COQUILLETIDIA) CRASSIPES van der Wulp.

*Bijd. Fauna Midden Sumatra, Dipt., 1892, 9 (Culex)*; Bonne-Wepster, *Meded. Dienst Volksgezondh. Ned.-Ind., xxviii, 1939, 12.*

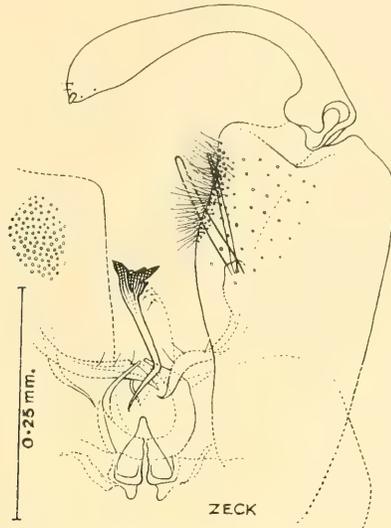


Fig. 8.—*Taeniorhynchus (Coquillettidia) crassipes* van der Wulp. ♂ terminalia, slightly lateral.

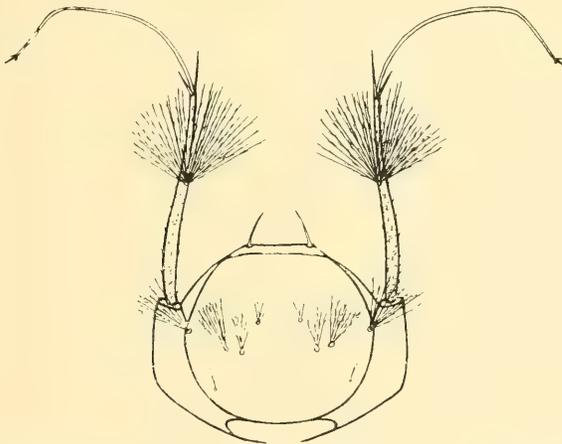


Fig. 9a.—*Taeniorhynchus (Coquillettidia) crassipes* van der Wulp. Larva, head.

Larva: Head a little broader than long, slightly angular, clypeal spines long and slender. Antennae very long, much more elongated than in the subgenus *Mansonioides*, for two reasons: the part from base to subapical spines is much longer (longer than the head) and the elongation itself alone is already much longer than the rest of the antennae.

Antennal hair closer to subapical hairs than to base, with 30 hairy branches, shorter than basal part of antenna, subapical hairs short, stiff; apical extension very long and delicate, with pointed flexible apex, a hair and a short leaflet, bulbous in appearance. This extension has the peculiar habit in the dead larva of curling up permanently like a corkscrew as soon as it is exposed to the air. From base to subapical spines the antennae are moderately covered with spines. Basal part up to implantation of antennal hair pigmented.

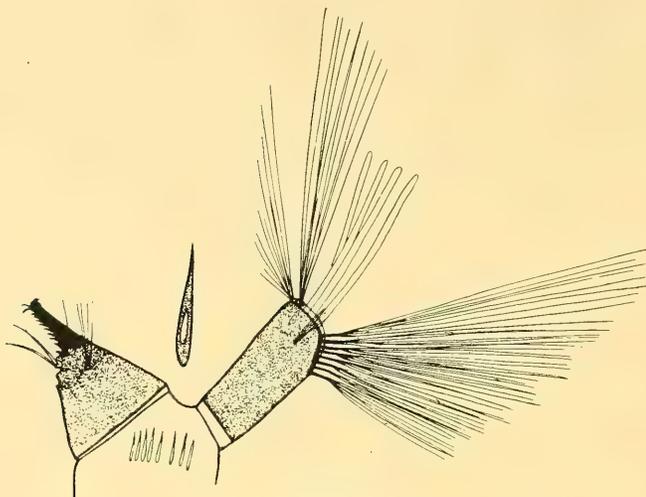


Fig. 9b.—*Taeniorhynchus (Coquillettidia) crassipes* van der Wulp.  
Larva, apical segments.

Head hairs: A moderately long, well developed, nine hairy branches, B shorter than A, seven hairy branches, C a little shorter than B, six hairy branches, d though shorter again than C, still very well developed with five naked branches, e two-branched, slender.

Comb on the eighth segment with eight long slender, sharp teeth, the points of the teeth easily breaking off. Air-tube very short, cone-shaped, provided with an apparatus to pierce tissue of aquatic plants, this apparatus black, slender, a little shorter than rest of air-tube with a very distinct sharp saw. At its base, laterally, a single stiff hair, dorsally at its base two flexible spines about as long as lateral hair. About the middle of the air-tube, which is  $1\frac{1}{4}$  times as long as wide, there is a four-branched hair, a little longer than half the width of the tube at base, moved away from the ventral line. No acus. Anal segment distinctly covered with very fine delicate hairs, slightly longer than air-tube, completely ringed by chitin, this chitinous ring about  $2\frac{1}{2}$  times as long as wide. Inner submedian hair with about twelve naked branches, the longest much longer than segment, the shortest shorter than width of segment at base; outer submedian hairs with ten naked branches equal in length, nearly twice as long as anal segment. Lateral hair delicate, four- or five-branched, inserted a little distance from apical margin, half as long as width of air-tube at place of insertion; ventral brush very well developed, with eight seven-branched naked hairs. No ventral hairs piercing the chitinous ring as in *Mansonioides*. Anal gills four, longer than segment, slender with blunt apex.\*

\* Since this paper was written, I have received a mounted preparation of the larva of this species from Mr. R. J. A. Lever, Suva, Fiji.

PETROLOGY OF THE HARTLEY DISTRICT. V.

EVIDENCE OF HYBRIDIZATION IN THE MOYNE FARM INTRUSION: A REVISION.

By GERMAINE A. JOPLIN, B.Sc., Ph.D., Linnean Macleay Fellow of the Society in Geology.

(Plate ii; One Text-figure.)

[Read 28th June, 1944.]

I. *Introduction.*

In 1931, I described a series of plutonic rocks from Hartley varying from ultra-basic to ultra-acid and showing a range of over 35% of silica. These were shown to be consanguineous and it was suggested that they represented the subsequent differentiation in place of three separate intrusions from an intratelluric reservoir—namely, gabbro, quartz-mica-diorite and granite. Later (Joplin, 1933) it was shown that instead of being normal differentiates, many of the basic types occurring in the Cox's River Intrusion were cognate hybrids which had arisen from the partial assimilation of solid hornblende-gabbro by quartz-mica-diorite magma.

In the 1931 paper the Moyne Farm Intrusion was described as a quartz-mica-diorite stock which had differentiated in place to give a slightly more basic margin and a tonalitic centre. Large blocks of diorite-gabbro and allied basic rocks were found enclosed in the diorite and a large apophysis of granite-porphyrty was described as an intrusion contemporaneous with the granitic phase.

I recently re-visited the area and found that excellent exposures of the tonalite now suggest that it is an acidified diorite which has probably arisen by interaction between the quartz-mica-diorite and the invading granite-porphyrty. Moyne Creek has removed some of the alluvium previously covering these outcrops, but the best exposures are to be found in material broken up by Dr. G. D. Osborne and some of his Technical College students.

Although the problem has not been entirely solved the field evidence leaves no doubt as to the hybrid origin of the tonalite, and the purpose of the present paper is to put this on record and to show that there has been a slight basification of the diorite by included blocks of gabbro involving changes similar to those described for the Cox's River Intrusion.

II. DIORITE-PORPHYRY REACTION.

1. *Field Occurrence.*

The Moyne Farm quartz-mica-diorite stock with its included basic rocks, tonalitic centre and transgressive granite-porphyrty apophysis has already been mapped (Joplin, 1931, Fig. 2). On the southern margin of the acid apophysis there are two tongues of basified porphyry, the larger being well exposed in the creek about 10 chains north-north-west of the farm-house in Por. 174, Par. of Hartley. The new exposures of tonalite occur in the creek just north of this point above the small eastern tributary stream.

The tonalite is intersected by numerous small quartz and aplite veins and by veins of basified porphyry which show sharp contacts to the invaded rock. These veins may sometimes carry small quantities of molybdenite and copper pyrites, and traces of malachite and azurite have been found. Quartz-epidote veins and segregations are fairly common and usually less sharp. Both the tonalite and the granite-porphyrty contain small epidotized and partly resorbed xenoliths.

A small inclusion (1 × 2 yds.) of much epidotized diorite occurs within the granite-porphyrty belt further upstream just below Cripps' orchard, Por. 175, Par. of Hartley.

## 2. The Parents.

### (a). *Quartz-mica-diorite.*

These rocks were fully described in the 1931 paper. Certain features described there, however, are now attributed to hybridization with the included basic rocks and are mentioned below (p. 136).

For the purpose of the present paper a brief description will be repeated. The fabric is hypidiomorphic to panidiomorphic granular and usually sub-ophitic. The constituent minerals are plagioclase, hornblende, biotite, quartz and accessories which include iron ore, apatite, rutile and sphene. Epidote, sericite, kaolin and some sphene are present as alteration products.

Andesine ( $Ab_{64}An_{36}-Ab_{55}An_{45}$ ) occurs in laths or elongated tabular crystals measuring from 0.75-2 mm. Hornblende and biotite form subidiomorphic crystals wrapping the feldspars and thus producing a sub-ophitic fabric (Plate ii, A). Quartz occurs as small interstitial grains.

### (b). *Granite-porphry.*

This was described in 1931 also, so that a brief résumé only need be given here.

Under the microscope the rocks are markedly porphyritic with phenocrysts varying from 3-6 mm. in a holocrystalline groundmass with a grain size of from 0.05-0.5 mm.

The phenocrysts consist of fairly fresh, as well as sericitized and saussuritized, tabular crystals of oligoclase ( $Ab_{71}An_{29}-Ab_{60}An_{40}$ ), corroded and strained crystals of quartz and tabular flakes of much altered biotite. The biotite is usually chloritized, and sphene and epidote granules are strung out in the direction of the cleavage, but it is often completely pseudomorphed by minute grains of iron ore (Plate ii, E). Altered plagioclase phenocrysts sometimes show a fresh, slightly more acid border.

The groundmass consists of a fine mosaic of quartz and kaolinized orthoclase, small grains of magnetite and flakes of altered biotite. Occasionally a little plagioclase is present with a slightly elongated habit. Veins and patches of epidote, chlorite, haematite and carbonates bear testimony to a period of deuteric activity. Apatite is rare but may occur in comparatively large crystals.

In the original description of this rock (Joplin, 1931) it was stated that biotite occurred in tabular flakes or as altered clusters of flakes. It is now believed that the latter occurrence is due to basification of the porphyry and that the clusters represent resorbed hornblende crystals or almost completely resorbed xenoliths of diorite.

The granite-porphry mass has been injected by aplites, quartz and quartz-epidote veins.

Rosival measurements have been made to determine the percentages of the various phenocrysts and of the groundmass and these are shown below (p. 133).

### (c). *Aplites.*

Aplite veins, rarely exceeding  $\frac{1}{2}$  in. in width, intersect the tonalite and granite-porphry. They are usually very fine grained and show a sharp contact with the invaded rock, but some, apparently belonging to a slightly earlier generation, are coarser in grain size, show slight hybridization and have imparted a local monzonitic fabric to the invaded rock which was evidently hot at the time of their injection.

The aplites commonly consist of a mosaic of quartz and orthoclase and sometimes a little micropertthite is present.

The occurrence of large hornblende crystals in some of the aplite veins indicates hybridization. The epidote-bearing varieties will be considered later in connection with deuteric activity.

Small quantities of metallic sulphides are often associated with the aplite veins and Dr. G. D. Osborne has observed that molybdenite sometimes occurs in thin plates on the wall of the vein.

## 3. The Hybrids.

As previously mentioned, the quartz-mica-diorite passes inwards into the tonalite, and though no actual contacts can be observed, this appears to be invaded by the

granite-porphry; thus the tonalite separates the basic diorite from the acid porphyry suggesting that it has been formed as the result of interaction between them.

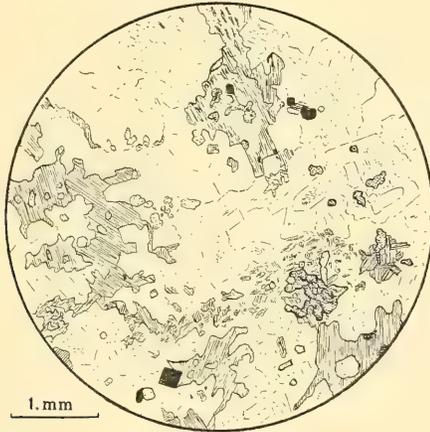
The tonalites are intersected by various hybrid veins and two large tongues of hybridized rock appear to have come from the granite-porphry apophysis. Several types of hybrid are therefore developed, and though it is believed that the basic parent in each case is the quartz-mica-diorite or a hybridized modification of it, the identity of the acid parent is often obscure. The acid material was evidently derived from the granite-porphry intrusion, but acidification may have been caused by the granite-porphry magma, by a partial magma or by an aplitic magma which appears to have been the end-phase in the consolidation of the granite-porphry magma.

In the following descriptions it is proposed to deal with the hybrids according to their structure and macroscopic appearance without regard to their parentage.

(a). *Tonalite (Acidified Diorite).*

The grainsize of these rocks is a little coarser than that of the quartz-mica-diorites. The fabric is very variable ranging from hypidiomorphic to allotriomorphic granular and there is often a tendency toward the sub-ophitic. All three fabrics may be recognized in different parts of a single slide (Fig. 1).

Plagioclase (Andesine,  $Ab_{68}An_{32}$ ) may occur either in subidiomorphic tabular crystals or as large irregular grains wrapping slightly more basic laths (Fig. 1). Zoning is common, the central zones usually being much saussuritized. Quartz is not so markedly interstitial as in the quartz-mica-diorites and its consolidation appears to have been in part contemporaneous with that of the plagioclase.



Text-fig. 1. ( $\times 12$ )

Tonalite showing allotriomorphic grains of quartz and plagioclase enveloping plagioclase laths. Note mass of chlorite with inclusions of sphene and outer border of biotite at top of figure; this probably represents a resorbed core of hornblende. Note also abundant apatite.

Hornblende, though quite fresh in some rocks, is more often represented by masses of chlorite, sphene and epidote intergrown with criss-cross flakes of biotite (Fig. 1). A little epidote occurs as independent fairly well developed crystals which seem to be of primary crystallization. Apatite is particularly abundant. Orthoclase is usually subordinate but becomes more prominent in the vicinity of aplite veins where it occurs in large plates and produces a local monzonitic fabric.

(b). *Fine-grained Porphyritic Types.*

These rocks occur as small veins in the tonalite and in two large tongues (about 17 chs. in length), which appear to be offshoots from the main apophysis of porphyry.

In the least acidified type, orthoclase is absent and the groundmass consists of laths of plagioclase interspersed with small irregular grains of quartz and plagioclase (Plate ii, B). Hornblende occurs with biotite and there is no phenocrystal development

of either ferromagnesian mineral. Mineralogically this rock resembles the parent diorite, but the development of rare plagioclase phenocrysts ( $Ab_{65}An_{35}$ - $Ab_{63}An_{37}$ ) and the presence of small granules of quartz and plagioclase among the felspar laths indicate a slight hybridization.

In a more acidified type, plagioclase phenocrysts ( $Ab_{69}An_{31}$ - $Ab_{66}An_{34}$ ) measure about 2 mm. and are often zoned. Occasional lath-shaped, slightly more basic crystals of plagioclase occur as inclusions in the felspar phenocrysts (Plate ii, C). There is only a slight distinction in size between flakes of biotite developed as small phenocrysts (about 1 mm.) and those occurring in the groundmass. Biotite is now the only ferromagnesian present and is occasionally chloritized. Small grains of quartz and orthoclase occur in the groundmass and a little magnetite, apatite and sphene are present. A rock of this type has been analysed (Table 1, Anal. IV).

In handspecimen these rocks are porphyritic with small, pink, tabular felspars measuring about 2 mm. in a fine dark groundmass.

(c). *Basified Porphyry.*

These rocks occur sporadically throughout the main belt of the granite-porphyry.

Except for the presence of a little more biotite and of small clots, the slightly basified types closely resemble the normal granite-porphyry. Under the microscope the altered biotite phenocrysts appear to be more numerous and the clots are seen to consist of patches of criss-cross biotite measuring up to 3 mm. across. These are usually chloritized and associated with granular sphene, epidote and iron ores (Plate ii, D). Apatite is very abundant and usually occurs within the biotite-chlorite clusters which probably represent almost completely resorbed xenoliths of diorite or tonalite. Corroded quartz phenocrysts showing undulose extinction, granulation and other evidence of strain, together with tabular phenocrysts of oligoclase still occur in these slightly basified types. The oligoclase is sometimes albitized. In the groundmass a plagioclase with a somewhat elongated habit occurs with quartz and orthoclase, and in some types small flakes of biotite and chlorite are numerous.

(d). *Veins and Segregations.*

It is shown below that both parent and hybrid rocks have been affected by a period of deuteric activity associated with the final consolidation of the porphyry, and in some cases it is a little difficult to distinguish between veins of distinct hybrid origin and those that are the result of a later deuteric activity. In addition to the veins, small elongated patches or segregations of epidote or of rather large hornblende crystals are not uncommon, and though I have been criticized (Grout, 1937) for applying the term "segregation" to a hybrid I believe that these coarser patches are of hybrid origin, the material having been dissolved out and carried by volatiles associated with the acid magma.

The most common type of hybrid vein is one containing large crystals of hornblende at the centre and passing out into an aplite at the margin. These usually measure about  $\frac{1}{2}$  in. or less and intersect the tonalite.

#### 4. *Origin of the Porphyry Phenocrysts.*

Three minerals occur as phenocrysts in the granite-porphyry and basified porphyry, namely—quartz, plagioclase and biotite. The quartz phenocrysts show corrosion, granulation, undulose extinction and every evidence of strain, and it seems fairly evident that they had crystallized prior to the injection of the granite-porphyry magma. The biotite phenocrysts also show resorption and advanced alteration into chlorite, sphene and epidote or are entirely pseudomorphed by granules of iron ore (Plate ii, E). Their appearance suggests an intratelluric origin. Although the plagioclase phenocrysts are often much sericitized or saussuritized, their margins are entire and there appears to be no evidence of either corrosion or strain. Occasionally altered felspars are surrounded by rims of fresh felspar and sometimes the occurrence of both altered and fresh felspar in the same rock suggests two generations of phenocrysts. Nevertheless, the bulk of evidence suggests selective deuteric alteration rather than two occurrences

of feldspar. The presence of basic cores, the absence of inverted zoning and the presence of groundmass minerals as inclusions all point to a growth *in situ*.

The origin of phenocrysts in plutonic rocks has been much discussed (Pirsson, 1899; Crosby, 1900; Watson, 1901) and various criteria have been listed to determine their intratelluric or contemporaneous origin. It seems to be agreed that the large tabular orthoclase phenocrysts of the porphyritic granites are contemporaneous and Nockolds (1932, 1933) has shown that plagioclase "phenocrysts" may grow within solid basic xenoliths enclosed in a granite magma. The "phenocrysts" of the fine-grained porphyritic hybrids have undoubtedly arisen in the way described by Nockolds and are therefore an inherent characteristic of their hybrid origin and not necessarily an inherited characteristic indicating that the porphyry was the acid parent.

In considering the hybridization processes it is important to try to ascertain the condition of the acid magma at the time of injection, and examination of the granite-porphyrries and the basified porphyries certainly suggests that the quartz and biotite phenocrysts and possibly a few of the plagioclase phenocrysts are intratelluric, and may not have taken part in the subsequent hybridization of the basic rocks.

#### 5. Deuteric Activity.

It was pointed out in the 1931 paper that the granite-porphyrries are rather susceptible to weathering and that it was difficult to determine how much of their alteration should be attributed to deuteric activity. It was finally decided that deuteric solutions were responsible for epidotization, chloritization, some oxidation and some carbonation whilst most of the oxidation (i.e., haematite, etc.) and carbonation was due to weathering. This generalization is probably fairly correct but it seems likely that sericitization, saussurization and kaolinization should be added to the list of deuteric processes.

The fact that all the porphyries show so much alteration invalidates any calculations that can be made in discussing the hybridization, and it will be seen below that it is impossible to reach any final conclusions regarding these processes.

#### 6. The Hybridization Process.

##### (a). Origin of the Tonalite.

As previously indicated, the field occurrence supplies the best evidence of the hybrid origin of the tonalite, especially the coarser texture and the occurrence of ferromagnesian clots. Except for the apparent instability of hornblende, the inclusion of feldspar laths in allotriomorphic grains, the sporadic zoning of feldspar and the sudden transitions in fabric, the microscopic evidence is unconvincing. Nevertheless, hybridization has undoubtedly occurred, and it seems to have advanced to such a stage that little evidence of it remains.

The foregoing discussion on the origin of the phenocrysts suggests that the acid liquid responsible for these reactions consisted of potential quartz, orthoclase, plagioclase and a little biotite. Rosiwal measurements were made to ascertain the percentage weights of the phenocrysts in the granite-porphyry with the following results:

	By calculation from Rosiwal Measurement.	By calculation from Chemical Analysis.
Quartz .. .. .	22.0	22.00
Plagioclase (fresh) .. .. .	12.8	12.86
„ (altered) .. .. .	8.6	8.62
Biotite .. .. .	5.1	5.60
Groundmass .. .. .	51.5	50.92
	<hr/> 100.0	<hr/> 100.00

Furthermore, slides were treated with hydrofluoric acid and sodium cobaltinitrite (Gabriel and Cox, 1929) to verify the observation that all the orthoclase was confined to the groundmass. I should like to take this opportunity of thanking Miss F. M. Quodling, B.Sc., for assistance with these staining tests. The composition of the supposed liquid fraction was then calculated on the assumption that it consisted of the groundmass plus the plagioclase phenocrysts, and an attempt was made to calculate

the composition of a hybrid rock formed by interaction between this liquid and the solid quartz-mica-diorite. Though it was realized that deuteric activity invalidated any such calculation, it was quite obvious that this alone could not be responsible for the impossible results obtained by calculations based on these assumptions. The removal of 22% of silica and of the small quantity of material forming the biotite necessitated the redistribution of the other oxides and the calculated percentage of alumina was far too high to satisfy any reasonable calculation.

Another attempt was made to calculate the composition of the acid liquid by including the altered plagioclase phenocrysts among the intratelluric phenocrysts and by calculating a proportion of them as sericite. This removed a little of the alumina as phenocrysts, but the results were equally unsatisfactory.

The most reasonable results were obtained by assuming that the whole of the granite-porphry took part in the reaction and the results of this calculation are shown in Table 1, below.

TABLE 1.

	I.	II.	IIIa.	IIIb.	IV.
SiO <sub>2</sub> .. .. .	54.37	69.78	62.06	61.67	66.65
Al <sub>2</sub> O <sub>3</sub> .. .. .	19.64	18.99	18.25	19.30	16.89
Fe <sub>2</sub> O <sub>3</sub> .. .. .	4.30	0.21	2.91	2.32	1.11
FeO .. .. .	4.87	1.06	2.94	3.03	1.67
MgO .. .. .	2.94	0.58	1.71	1.80	1.46
CaO .. .. .	8.07	1.24	4.90	4.78	3.02
Na <sub>2</sub> O .. .. .	2.55	3.65	3.12	3.07	3.14
K <sub>2</sub> O .. .. .	1.01	3.42	1.61	2.17	4.54
H <sub>2</sub> O+ .. .. .	0.96	0.48	1.34	0.85	0.58
H <sub>2</sub> O- .. .. .	0.11	0.13	0.16		0.13
TiO <sub>2</sub> .. .. .	1.14	0.23	0.60	0.70	0.42
P <sub>2</sub> O <sub>5</sub> .. .. .	0.34	0.19	0.24	0.27	0.29
MnO .. .. .	0.07	0.01	0.09	0.04	0.02
	100.37	99.97	99.93	100.00	99.92
Sp. Gr. .. .. .	2.86	2.66	2.76		2.76

- I. Quartz-mica-diorite (Basic Parent), Moyne Farm, Little Hartley. Anal. G. A. Joplin. Proc. LINN. Soc. N.S.W., 56, 1931, 53.
- II. Granite-porphry (Possible Acid Parent), Moyne Farm, Little Hartley. Anal. G. A. Joplin.
- IIIa. Tonalite (Acidified Diorite), Moyne Farm, Little Hartley. Anal. G. A. Joplin. Proc. LINN. Soc. N.S.W., 56, 1931, 53.
- IIIb. Theoretical Hybrid consisting of 52% of Quartz-mica-diorite (I) and 48% of Granite-porphry (II).
- IV. Fine-grained Porphyritic Hybrid occurring as vein in Tonalite, Moyne Farm, Little Hartley. Anal. G. A. Joplin.

If such be the case, then the intratelluric phenocrysts must have been dissolved and reprecipitated, and this seems possible if the basification of the liquid be assumed.

There is no doubt that the quartz-mica-diorite stock consolidated from the margin towards the centre, and structures in the tonalite indicate that it was in part solid at the time of the acid invasion. Thus the "tonalite" probably consisted of a crystal mesh of the more basic minerals and an interstitial acid liquid residuum, which represented the final residual liquid of the quartz-mica-diorite magma. If this mesh were invaded by a far more acid liquid carrying solid quartz, mingling of the two liquids would bring about the solution of the quartz, since being low in the reaction series, it would no longer be in phasal equilibrium with the new, slightly more basic liquid. The liquid would not be capable of dissolving the constituents of the crystal mesh as they are higher in the reaction series, but reaction would take place and the hornblende of the tonalite thus appears to be somewhat unstable and the felspar sometimes zoned. The hybridized liquid would finally crystallize like a normal product of differentiation and this would probably account for the normal appearance of the hybrid rock.

(b). *Origin of the Porphyritic Hybrids.*

Reference to the petrography of the fine-grained porphyritic hybrids indicates that the basic parent was a solid rock at the time of the acid invasion. Thus in the least

acidified type the only evidence of hybridization is to be found in the presence of tiny quartz and feldspar granules between the plagioclase laths and in the occasional development of plagioclase "phenocrysts" such as those described by Nockolds (1932) as forming within a solid rock immersed in a liquid. The more advanced hybrids also indicate reaction between a solid diorite or tonalite and a liquid, and show structures similar to those observed by Nockolds in xenoliths.

The quartz-mica-diorite was undoubtedly a solid when injected by the granite-porphry, but there is no evidence of its immersion in the acid liquid. The occurrence of these types in tongues and veins suggests that the solid basic rock has been permeated or soaked by an acid liquid along certain definite channels. This raises two difficulties regarding the parentage—first, it seems unlikely that the whole of the basic rock would take part in the reaction, and second, it is difficult to envisage an acid liquid containing intratelluric phenocrysts permeating solid rocks in this way.

A graphical solution of the problem was attempted by assuming first that the whole of the granite-porphry magma hybridized a part of the diorite. The silica-percentages of the granite-porphry and of the hybrid were used as abscissae and the other oxides as ordinates. On producing the lines thus plotted, it was found that the curve for  $\text{Na}_2\text{O}$  intercepted the  $\text{SiO}_2$  base line at 53.5%. This was presumably the composition of that part of the diorite that had been selectively assimilated, but material containing this amount of silica has a composition quite unlike anything that could be regarded as part of a basic rock. Potash is extraordinarily high, silica and lime fairly high and alumina extremely low. The potash could be accounted for by assuming that biotite was selectively reacted with, but this would not account for the low alumina and high lime and silica. The high lime might be due to the assimilation of basic plagioclase, but this would necessarily lower the amount of biotite and therefore the amount of potash and could not account for the other discrepancies.

The assumption was then made that the whole of the diorite took part in the reaction and another graphical attempt was made to ascertain the composition of the acid liquid. This was done by plotting the analyses of the quartz-mica-diorite and of the hybrid on a variation-diagram as described above. It was found that total iron intercepted the base line for silica at 72% and it was assumed that a liquid containing 72% of silica was responsible for the hybridization. However, when the other oxides were examined it was found that lime was too low for a normal granite or aplite and that potash and magnesia were too high. These discrepancies might be explained by assuming that there has been a selective diffusion of the magnesia from the basic parent, that lime had been removed as epidote during deuteric action and that potash had been added in the form of orthoclase during the period of aplite injection or as sericite replacing lime-soda-feldspar during the deuteric period. The fact that there is scope for such speculation weakens any argument that can be put forward.

Various attempts were made to calculate the composition of a phenocryst-free liquid as was done in attempting to ascertain the percentage of the tonalite, but all results were unsatisfactory.

The assumption was then made that the hybrids had arisen by interaction between solid diorite and an aplitic magma, and the analysis of an aplite from another part of the Hartley district was used as a basis for this calculation. This rock contains nearly 77% of silica and to produce a hybrid containing about 66% required a mixture of 55% aplite and 45% diorite. Though comparable results could be obtained for silica and alumina there were great discrepancies between all other oxides, the calculated rock being far too basic with respect to these oxides. Obviously more of the acid rock required to be taken, but as this gave too high a result for silica, it is evident that the acid parent was more basic than the aplite.

Actually the most satisfactory results were obtained by using the diorite or the tonalite and the whole of the granite-porphry as the basis of calculation. These figures were comparable with those of the actual hybrid except for alumina and potash, the former being too high and the latter too low. During the period of deuteric activity the actual hybrid rock may have suffered alkalization and potash may have been introduced as described by Browne and White (1928). Nevertheless, on this

assumption it was postulated that phenocrysts suspended in an acid liquid passed into a solid basic rock, and as no mechanism for such an invasion can be explained, nor can it be assumed that the phenocrysts dissolved during hybridization, it is considered unwise to present these calculations and thus to create the impression that the results are considered to be reliable.

It is not unlikely that a part of the granite-porphry magma selectively reacted with a part of the quartz-mica-diorite and that subsequently the whole has been modified by deuteritic activity.

In the case of the basified porphyries that contain all the phenocrysts of the porphyries the presence and final resorption of diorite xenoliths in the magma can be demonstrated.

### III. DIORITE-GABBRO REACTION.

It was noted in the 1931 paper (p. 40) that the quartz-pyroxene-diorites and diorite-gabbros occur as inclusions in the quartz-mica-diorite in the Moyne Farm Intrusion, but at the time it was not recognized that certain features, described as characteristics of the diorite, were really characteristic only of a basified type formed by the partial assimilation of these masses.

Reaction between solid hornblende-gabbro and quartz-mica-diorite magma has been fully discussed in connection with the Cox's River Intrusion (Joplin, 1933), and as the changes are very similar, it is not proposed to give detailed petrographical descriptions or to discuss the hybridization process of the basified diorite here. Nevertheless, it seems useful to mention the main characters that can be attributed to basification and to refer to similar observations in the Cox's River Intrusion.

Thus it was noted (Joplin, 1931, p. 35) that the central zone of some of the tabular felspar crystals of the quartz-mica-diorites was crowded with small granular inclusions, and that this zone was clear as compared with a sericitized outer zone. I now believe that this clear felspar, containing granular inclusions, indicates recrystallization of the earlier basic felspar and that the slightly altered outer rim is composed of a more acid, deuterically altered plagioclase deposited during hybridization (Joplin, 1933, 1935, 1936). Furthermore, re-examination of some of the quartz-pyroxene-diorites and of the more basic quartz-mica-diorites reveals further evidence which can be attributed either to recrystallization followed by hybridization or to hybridization alone. Thus

TABLE 2.

	I.	II.	IIIa.	IIIb.
SiO <sub>2</sub> .. ..	54.37	44.79	46.49	46.44
Al <sub>2</sub> O <sub>3</sub> .. ..	19.64	19.56	19.22	19.63
Fe <sub>2</sub> O <sub>3</sub> .. ..	4.30	6.01	6.68	5.75
FeO .. ..	4.87	7.79	6.02	7.34
MgO .. ..	2.94	6.16	5.89	5.67
CaO .. ..	8.07	11.81	10.88	11.25
Na <sub>2</sub> O .. ..	2.55	1.21	2.16	1.43
K <sub>2</sub> O .. ..	1.01	0.06	0.65	0.21
H <sub>2</sub> O + .. ..	0.96	0.64	0.96	} 0.79
H <sub>2</sub> O - .. ..	0.11	0.10	0.17	
TiO <sub>2</sub> .. ..	1.14	1.14	0.92	1.14
P <sub>2</sub> O <sub>5</sub> .. ..	0.34	0.18	0.40	0.21
MnO .. ..	0.07	0.15	0.20	0.14
CO <sub>2</sub> .. ..	—	tr.	tr.	—
	100.37	99.60	100.64	100.00
Sp. Gr. ..	2.861	3.055	2.967	

I. Quartz-mica-diorite. Repeated from Table 1.

II. Recrystallized Pyroxene-gabbro. Cox's River Intrusion, Little Hartley. Anal. G. A. Joplin. PROC. LINN. Soc. N.S.W., 58, 1933, 146.

IIIa. Diorite-gabbro, Moyne Farm, Little Hartley. Anal. G. A. Joplin. Ibid, 56, 1931, 53.

IIIb. Theoretical Hybrid consisting of 16% of Quartz-mica-diorite (I) and 84% of Pyroxene-gabbro (II).

plagioclase sometimes shows mottling (Joplin, 1933, p. 131) and much of the amphibole is a fibrous variety probably pseudomorphing original pyroxene.

As these basic types in the Moyne Farm Intrusion have much in common with types in the Cox's River Intrusion, it seems likely that they have had a similar origin, namely, reaction between solid gabbro and a quartz-mica-diorite magma. The blocks of diorite-gabbro on Moyne Farm would, therefore, represent slightly acidified gabbros, the quartz-pyroxene-diorites highly basified diorites and the basic types of quartz-mica-diorite slightly basified rocks. The Cox's River Intrusion is only about 1½ miles west of the Moyne Farm Intrusion, and it is reasonable to assume that the earlier gabbro intrusion had a similar composition in both places. In Table 2 it is shown that a theoretical rock consisting of 84% of the Cox's River gabbro and 16% of the Moyne Farm quartz-mica-diorite compares reasonably well with the actual analysis of the diorite-gabbro on Moyne Farm. The higher alkalis in the actual rock suggest a selective diffusion of these constituents, and the discrepancy between the iron oxides is seen to be only apparent when the figures for total iron are examined; thus in (a) total iron equals 13.37 and in (b) it is 13.90. The higher ferric iron and soda in the actual diorite-gabbro hybrid are possibly due to slight deuteric alteration.

#### IV. SUMMARY.

It has been shown that the granite-porphry magma invaded the quartz-mica-diorite whilst the latter was incompletely consolidated, its centre being a crystal mesh with an interstitial liquid. At the time of its injection the granite-porphry consisted of a fairly acid liquid carrying solid quartz. This liquid hybridized the liquid phase of the diorite, and the solid quartz, thus no longer being in phasal equilibrium, dissolved. The liquid also reacted with the solid phase of the diorite, that is, with the crystal mesh. The resulting hybrid rock was a tonalite bearing some resemblance to a normal product of differentiation.

The granite-porphry magma, or a partial magma related to it, also permeated the solid diorite and gave rise to fine-grained porphyritic hybrids that usually have a vein-like occurrence. As many of these veins invade the tonalite and show sharp contacts with it, it is believed that at least some part of the granite-porphry remained liquid for some time after the complete consolidation of the tonalite and that some of these veins may be secondary hybrids formed by reaction between the acid parent and the earlier formed hybrid.

Assimilation, reaction and the long period of fluidity were made possible by volatiles, the presence of which is indicated by a period of deuteric activity.

Finally it has been shown that the diorite was partly basified by the assimilation of solid gabbro prior to the invasion of the granite-porphry. The fact that the quartz-mica-diorite shows an earlier basification and a later acidification indicates its existence as a magma, and though it is now recognized that the Hartley plutonic complex contains many cognate hybrids, my earlier contention (1931) that there were three separate injections of magma from an intercrustal reservoir, namely—gabbro, quartz-mica-diorite and granite, is thus borne out.

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## EXPLANATION OF PLATE II.

(× 12.)

A.—Quartz-mica-diorite showing hornblende and biotite partly wrapping laths of plagioclase to produce a sub-ophitic fabric.

B.—Fine-grained porphyritic hybrid (slight acidification) showing plagioclase phenocrysts with saussuritized basic cores in a groundmass consisting of hornblende, biotite, laths of plagioclase and small grains of plagioclase and quartz.

C.—Fine-grained porphyritic hybrid (Table 1, Anal. IVa), showing plagioclase phenocrysts with included laths, flakes of biotite and small masses of chlorite, sphene and apatite in a fine mosaic of quartz and orthoclase.

D.—Basified porphyry showing large plagioclase phenocrysts and clots of biotite, sphene and apatite in a quartz-orthoclase groundmass. Note slight graphic intergrowth on right.

E.—Granite-porphyry showing corroded quartz phenocrysts with pseudo-inclusions, sericitized plagioclase phenocrysts and flakes of biotite pseudomorphed by granules of iron ore. The groundmass consists of quartz and orthoclase.

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## BRYOZOA FROM THE PERMIAN OF WESTERN AUSTRALIA.

PART I. CYCLOSTOMATA AND CRYPTOSTOMATA FROM THE NORTH-WEST BASIN AND  
KIMBERLEY DISTRICT.

By JOAN CROCKFORD, M.Sc., Linnean Macleay Fellow of the Society in Palaeontology.

(Plates iv-v; Fifty-two Text-figures.)

[Read 30th August, 1944.]

*Introduction.*

The marine Permian strata of Western Australia contain an abundant and varied bryozoan fauna, of which only a small part has so far been described. In this paper six species whose descriptions were originally published by R. W. Bretnall in 1926 (as *Coscinium* (?) *australe* Bretnall, *Sulcoretepora* (?) *meridianus* Etheridge, *Rhombopora multigranulata* Bretnall, *R. mammillata* Bretnall, *Streblotrypa marmionensis* Etheridge, and *S. etheridgei* Bretnall) are revised from a study of the type material, a number of new species belonging to the genera *Fistulipora*, *Hexagonella*, *Fenestrellina*, *Minitya*, *Penniretepora*, *Septopora*, *Synocladia*, *Rhombocladia*, and one new genus, *Strebocladia*, are described and figured, and record is made of the occurrence in Western Australia of species of *Goniocladia*, *Fenestrellina*, and *Protoretepora*. A small collection of specimens recorded previously (Raggatt, 1936, 128) from the Callytharra as species which were originally described from the Upper Pennsylvanian Graham Formation of Texas are amongst those described in this paper.

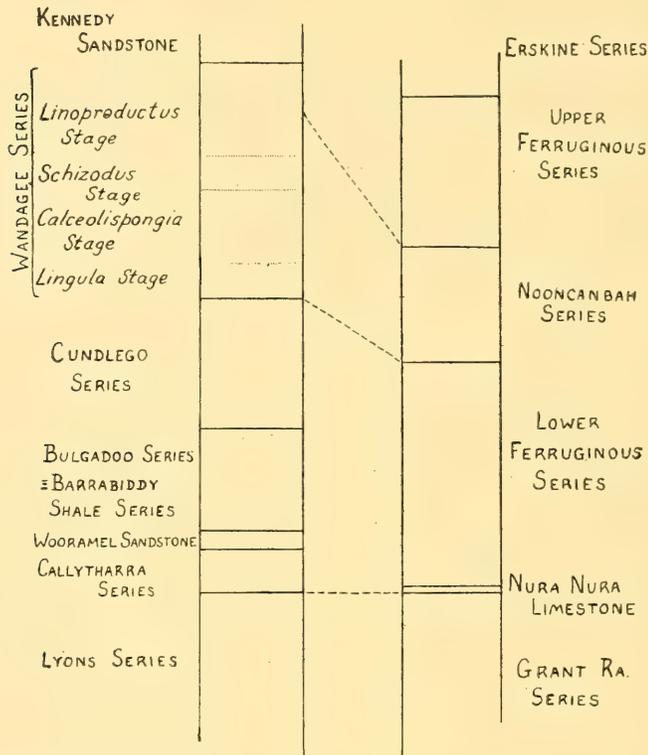
The collections on which this work has been based comprise specimens from the Barrabiddy shales, and the Cundlego, Wandagee, and Nooncanbah Series from the University of Western Australia Collection, and specimens from the Australian Museum Collection (from the Wandagee and Nooncanbah Series) and the Commonwealth Palaeontological Collection (from the Callytharra Series). My thanks are due to Dr. C. Teichert, of the University of Western Australia, to Mr. Fletcher, of the Australian Museum, and to the Commonwealth Palaeontologist, Miss Crespin, for lending me these specimens and for the information they have so willingly given me about them, and to Dr. Ida Brown for the help she has given me during the preparation of this paper. The photographs were taken by Mr. H. G. Gooch.

The fauna contained in the collections available is extremely varied, and although species belonging to some of the most important genera are described in this paper, other genera of equal importance are not touched upon—for example, no Batostomellidae are described here, although Stenoporids form one of the most abundant groups in the fauna, and *Batostomella* and closely allied genera are also common and represented by a large number of species. No general discussion of the age of the fauna is, therefore, attempted here.

*Fistulipora*, although it is one of the most abundant and characteristic forms in the fauna, has not hitherto been recorded from these beds, apart from the records as *Dybowskiella*, made by Chapman (in Raggatt, 1936, 128)—quoted by Raggatt and Fletcher (1937, 171)—and by Teichert (1940, 383, 406). It is represented by a large number of species—massive, fine and coarse ramose, and incrusting forms—of which only the massive species from the Wandagee and Nooncanbah Series are described in this paper. It was expected that an examination of this group of massive species, which is abundantly represented in the Permian of Timor, would reveal some species identical with the Timor forms, to which some of the Western Australian species show a general

## NORTH-WEST BASIN

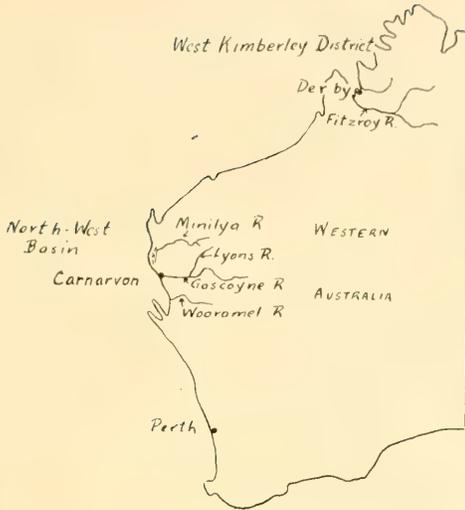
## KIMBERLEY DISTRICT



Text-fig. A.—Generalized sections of the Upper Palaeozoic succession in the North-West Basin and the Kimberley district of Western Australia; the base of the Callytharra Series and of the Nura Nura Limestone is approximately the horizon of the Sakmarian-Artinskian boundary; the succession shown for the North-West Basin is that found in the Minilya River district. (Taken mainly from Teichert, 1941, 390.) Scale of the order of 2,000 feet : 1 inch.

external resemblance. Examination of the internal structure of the massive Western Australian species has, however, shown that there is no massive species so far known which could be at all closely compared with any species from Timor, although the general aspect of the species is similar, and they clearly represent a similar stage in the development of the genus. The related form *Hexagonella* is one of the most abundant genera in this bryozoan fauna. The species here described are, with the exception of *Hexagonella australe* (Bretnall), all from the Wandagee or Nooncanbah Series. The three previously described species of this genus, from the Salt Ra. of India and the Permian of Timor, are all species with comparatively narrow, ribbon-like branches, and this group of species is represented in the Callytharra by a number of species, of which *Hexagonella australe* is one. Species of *Hexagonella* with broad, frond-like zoaria are less common in the Callytharra than the ribbon-like species, but in the higher beds of the Wandagee and Nooncanbah Series, frond-like species quite distinct from any previously described forms are so far the only ones known to occur. So far no species of *Fistulipora* or of *Hexagonella* has been found common to the Wandagee and the Nooncanbah.

"*Sulcoretepora*" *meridianus* (Etheridge) differs from *Sulcoretepora*, which it closely resembles externally, in its internal structure, which is not closely comparable with that of any genus so far described. *Goniocladia timorensis* Bassler, which is here recorded from the Nooncanbah Series, was originally described from the Basleo Beds of Timor.



Text-fig. B.—Sketch map of Western Australia, to show the districts from which the specimens described in this paper were collected.

The species of *Fenestrellina* and *Minilya* here recorded and described are specimens which were previously recorded from the Callytharra by Chapman (in Raggatt, 1936, 128) as *Fenestella pectinis* Moore and *Fenestella spinulifera* Moore; these two species were originally described from the Wayland Shale of the Graham Formation (Pennsylvanian) of North-Central Texas. These identifications are not confirmed here; one of the specimens recorded as *Fenestella pectinis* is here identified as *Fenestrellina horologia* (Bretnall), of which *F. parviuscula* Bassler, described from the Bitaoeni and Basleo Beds of Timor, and since recorded from the Permian of Vancouver Island, is a synonym; *F. horologia* occurs also in the Wandagee and Nooncanbah Series, in the Permian of the Northern Territory, and in the Dilly Stage in Queensland; and three of the specimens recorded as *Fenestella spinulifera* are identified as *Fenestrellina affluensa* (Bretnall); the remaining specimens are referred to new species of *Fenestrellina* and *Minilya*. Chapman (in Raggatt, 1936, 128) also recorded *Pinnatopora trilineata* var. *texana* Moore, described from the Wayland Shale of Texas, from the Callytharra; this species from the Callytharra is here described as *Penniretepora triporosa*, n. sp., and although it and *P. fossata*, n. sp., show a strong general resemblance to species described from the Wayland Shale, no species identical with any North American form has so far been found. The species of *Septopora* and *Synocladia* described here could not be confused with any previously described species, but are typical members of these genera, both of which are widespread in late Palaeozoic deposits in other parts of the world.

*Rhabdomeson shanse* Reed, from the Anthracolithic of Burma, is here considered a synonym of *R. mammillata* (Bretnall), from the Nooncanbah Series, and *R. bispinosa*, n. sp., from the Callytharra, is a form very similar to *R. consimile* Bassler, from the Basleo and Amarassi Beds of Timor. It is also considered probable that specimens described from the Bitaoeni and Basleo Beds of Timor as *Streblotrypa germana* Bassler should be referred to *S. marmionensis* Etheridge, which is a very common and widespread form in Western Australia. The occurrence in Western Australia of two very rare genera, *Rhombocladia*, of which, although it is known to occur in North America, Italy and Russia, only two species have so far been described, and *Streblocladia*, n. gen., to which *Septopora* ? *elliptica* Warthin from the Pennsylvanian of Oklahoma is also referred, is interesting in emphasizing the wide and representative variety of bryozoan genera present in the Western Australian Permian, and their presence also emphasizes the fact that, although no species have so far been found common to these two widely separated deposits, there is a strong similarity in the general type of bryozoan fauna between the Callytharra and the Graham Formation of Texas and rocks of equivalent

age in Oklahoma, probably due to deposition in a similar type of facies and at a not very widely differing age. The Western Australian fauna on the whole, as can be seen from the species described in this paper, shows a much closer general similarity to the faunas of Timor and of the Salt Ra. than to the Permian faunas of Eastern Australia, where the range of genera present is much more restricted—*Fenestrellinidae* and *Batostomellidae*, with a few *Rhabdomesontidae* and *Acanthocladiidae*, are the only families so far known to occur, although abundant faunas with a wide variety of species are developed—but a few species are common to Eastern and Western Australia, as for example *Protoretetpora ampla* (Lonsdale), which occurs in New South Wales in the Muree Stage of the Upper Marine Series, and is recorded in this paper from the Nooncanbah Series.

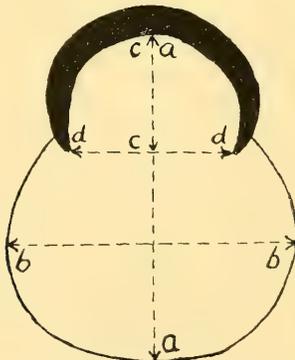
The holotypes of three of the species revised here, "*Sulcoretetpora*" *meridianus* (Etheridge), *Rhombopora multigranulata* Bretnall, and *Rhabdomeson mammillata* (Bretnall), form part of a collection of specimens numbered 10930, Western Australian Geological Survey Collection. Bretnall gave the locality of these specimens as Gascoyne River district, but they are identical in matrix, in the preservation of the fossils, and in the fauna present, to other specimens used by Bretnall in the course of his work and now in the Australian Museum Collection, whose locality is catalogued as Mt. Marmion; comparison of these with many specimens from this locality in the University of Western Australia Collection leaves little doubt that all of these specimens are from the same locality, and that the type locality of these species should be corrected to Mt. Marmion. Other specimens whose locality was given by Bretnall as Gascoyne River district, e.g., 2/2405, W. Aust. G.S. Colln., on which are the holotypes of *Fenestrellina horologia*, *F. affluensa*, and *Ramipora ambrosoides*, are quite distinct from those labelled 10930, being shaly limestones, probably from the Callytharra Series in the Gascoyne River district.

#### DESCRIPTION OF SPECIES.

##### Order CYCLOSTOMATA Busk.

##### Family FISTULIPORIDAE Ulrich.

In measurements of specimens of *Fistuliporoids*, the spacing of the zooecia is here given, in species with irregular arrangement of the apertures, as the number of zooecia in a field of 7 sq. mm., the measurements always being made exclusive of maculae, as when the apertures are not regularly arranged this gives a clearer idea of their spacing than do the customary linear measurements of distance between the apertures. In measuring the size of the zooecial tubes, the longer and shorter diameters of the tubes were measured where the tubes are not deeply indented by the lunaria, otherwise the measurements are given (see Text-figure C) as suggested by Nikiforova (1933, Text-fig. 3).



Text-fig. C.—Diagrammatic transverse section through a zooecium of *Fistulipora*, marked to show the method used in this paper for measuring the zooecia.

Genus *FISTULIPORA* McCoy, 1850.

*Fistulipora* McCoy, 1850, 131; *Fistulipora* McCoy, Ulrich, 1896, 382, 474; Bassler, 1929, 41.

*Genotype*: *Fistulipora minor* McCoy, 1850.

*Range*: Ordovician to Permian.

*Zoarium incrusting to massive or ramose, surface with monticules or maculae composed of aggregations of vesicles or of enlarged zooecia; zooecial tubes with faint to strongly developed lunaria, and usually with diaphragms; interzooecial spaces occupied by vesicular tissue, sometimes replaced by dense tissue near the surface.*

The massive species, only, of *Fistulipora* from the Wandagee and Nooncanbah Series, are described in this paper.

*FISTULIPORA VACUOLATA*, n. sp. Text-figs. 1, 2.

*Horizon and locality*: Limestone horizon, highest fossil horizon of Nooncanbah Series, on east side of Mt. Marmion, near gully from saddle. Coll. Caltex.

*Holotype*: Specimen 22126, Univ. W. Aust. Colln.

*Massive Fistulipora, maculae small; zooecia large, not indented by the thick lunaria, diaphragms numerous; vesicular tissue very coarse.*

The zoarium is massive and fairly large, the largest specimen, which is incomplete, being about 7 cm. long and up to 4 cm. in height. Generally the zooecial tubes are continuous throughout the height of the colony, but some discontinuous layers are developed. The surface is not well enough preserved to show the maculae; these maculae are shown in transverse sections, and are composed of aggregations of vesicles about 1 mm. in diameter.

The zooecia are tubular, rather thick walled, rounded in cross-section, and not usually indented by the lunarium. This lunarium occupies one-third to one-half of the circumference of the tube, and may be very strongly thickened, though this is not always the case; in spite of its frequently great thickness, it is often not conspicuous in sections of these specimens, since the tubes are not indented, and the specimens from this locality are often very iron-stained, so that details of their structure are not always clearly shown. The zooecia usually measure: a, 0.38–0.55 mm.; b, 0.36–0.57 mm.; c, 0.06–0.16 mm.; d, 0.28–0.48 mm.; but both larger and smaller zooecia sometimes occur. The number of zooecia in 7 sq. mm. is 15 to 22. The diaphragms are rather thick; their spacing is very variable, but usually they are between 0.4 and 1.25 mm. apart; from 4 to 7 diaphragms occur in 3 mm. The vesicles are angular and very coarse, particularly in longitudinal section; they occur usually in one or two rows between adjacent zooecia, but they do not always completely separate the zooecia; at irregular intervals throughout the zoarium zones are developed in which the vesicles are rather flattened for a short distance—about 1 mm.; they are not replaced by dense tissue near the surface.

*FISTULIPORA CRESCENS*, n. sp. Pl. iv, Fig. 1; Text-figs. 7, 8.

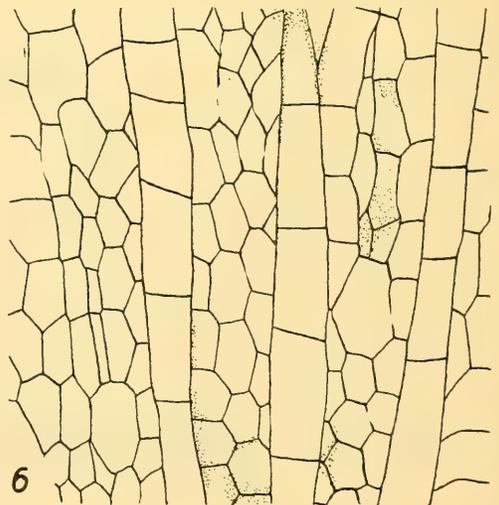
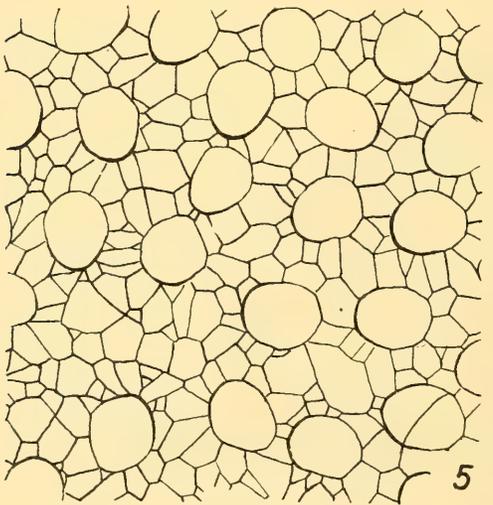
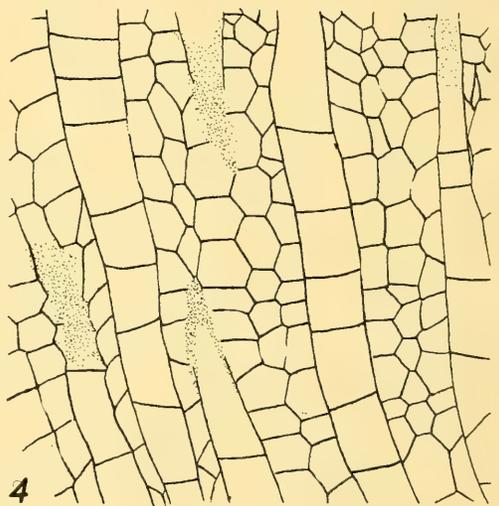
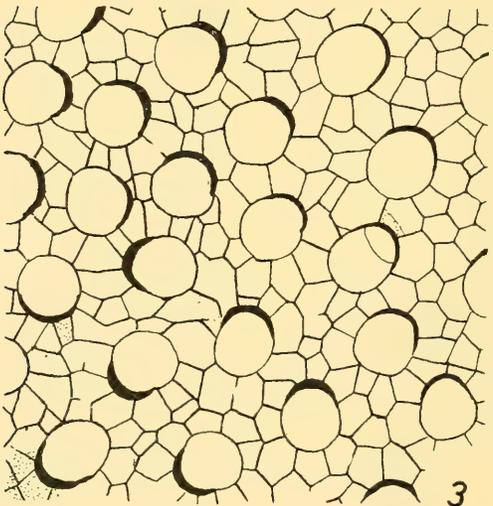
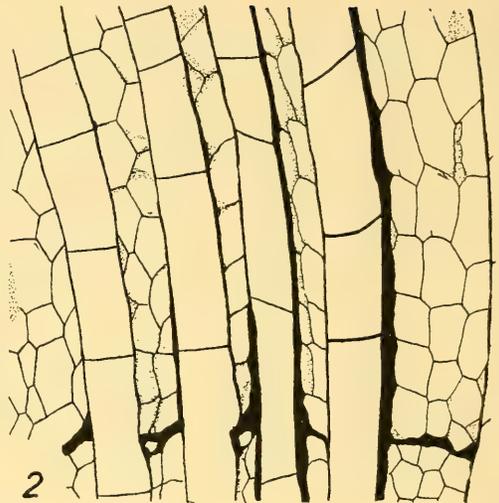
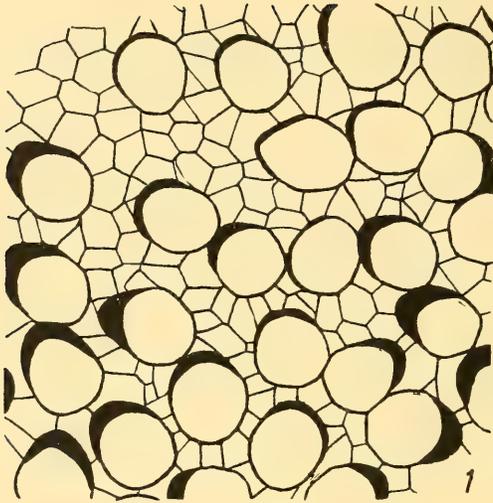
*Horizon and locality*: Highest fossil horizon of Nooncanbah Series, south-east side of Mt. Marmion, near foot of slope. Coll. C. Teichert.

*Holotype*: 22123a, Univ. W. Aust. Colln.

*Massive Fistulipora; zooecia small, strongly indented by thick lunaria; diaphragms thick, irregularly spaced; vesicular tissue simulating mesopores in vertical section.*

The zoarium is massive in appearance, being built up of a number of discontinuous lamellae of variable width, some lamellae being very narrow, while in other parts of the same colony individual zooecial tubes may extend throughout the zoarium. The colonies are irregular in shape, reach 5 cm. in length and are up to 2.5 cm. in height. The sides of the colony may be infolded near the base, which is covered by a thin, concentrically wrinkled theca. Occasional small maculae, composed of aggregations of vesicles and appearing solid at the surface, occur on the surface of the colony, but they are not regularly arranged.

The zooecia are erect, and are strongly indented by the ends of the lunaria; the size of the tubes in cross-section is: a, 0.32–0.41 mm.; b, 0.29–0.43 mm.; c, 0.08–0.14 mm.; d, 0.19–0.25 mm.; they are closely spaced, 18 to 29 in 7 sq. mm. Lunaria are well



developed and fairly strongly thickened; they occupy about one-quarter to one-third of the circumference of each tube; at the surface they project as hoods over the apertures. The rather thick diaphragms are irregularly spaced, but are most often between 0.45 and 0.75 mm. apart, 4 to 7 occurring in 3 mm. The zooecial tubes are separated from one another by flattened vesicles, simulating closely tabulated mesopores in vertical section; these vesicles are angular in cross-section, and occur in one or two, less often more, rows between adjacent zooecia; they are not infilled by dense tissue as they approach the surface, though there is a tendency for them to become thicker walled and less angular.

FISTULIPORA WADEI, n. sp. Text-figs. 5, 6.

*Horizon and locality:* Highest fossil horizon of Nooncanbah Series, south-east side of Mt. Marmion, near foot of slope. Coll. C. Teichert.

*Holotype:* 22124, Univ. W. Aust. Colln.

*Massive Fistulipora; zooecia large, with thin lunaria, which do not indent the tubes; diaphragms numerous; vesicular tissue coarse.*

The zoarium is massive, hemispherical in shape; it is comparatively small, about 3.25 cm. long and 2.5 cm. high; one weathered surface gives an oblique section through the zoarium, and is marked by ridges representing pauses in growth, which can be traced in sections as a line of flat-topped vesicles, but the zooecia are continuous throughout the colony. The surface is rather weathered, and maculae are not well shown on it, though they appear in sections as aggregations of vesicles about 1 mm. in diameter, irregularly arranged, but of fairly frequent occurrence.

The zooecia are oval in cross-section; they are not usually indented by the lunaria, which are only slightly thickened but extend around one-third to one-half of the circumference of each tube. Measurements of the zooecia are: a, 0.41–0.49 mm.; b, 0.36–0.44 mm.; c, 0.01–0.16 mm.; d, 0.3–0.36 mm. There are rather constantly 17 to 18 zooecia in 7 sq. mm. The diaphragms are very thin and irregularly spaced, being usually between 0.3 and 1.25 mm. apart, with from 4 to 6 in 3 mm. The vesicles are very coarse, angular, and thin walled, and are not infilled by dense tissue near the surface; usually there are one or two rows of vesicles between the zooecia, but rarely adjacent zooecia are in contact.

FISTULIPORA COMPACTA, n. sp. Text-figs. 3, 4.

*Horizon and locality:* Unknown horizon of Calceolispongia Stage of the Wandagee Series, Syncline west of Coolkilya Pool, Minilya R.

*Holotype:* 22129, Univ. W. Aust. Colln.

*Massive Fistulipora; zooecia large, usually little indented by slightly thickened lunaria; diaphragms numerous; vesicular tissue coarse.*

The zoarium is small and massive, reaching a maximum height of 2.3 cm. and width of 2.1 cm. The base of the colony is sub-circular, concave, and covered by a thin theca. The large zooecial apertures are protected by slightly raised lunaria; the vesicles are closed at the surface. Small maculae composed of aggregations of vesicles occur irregularly.

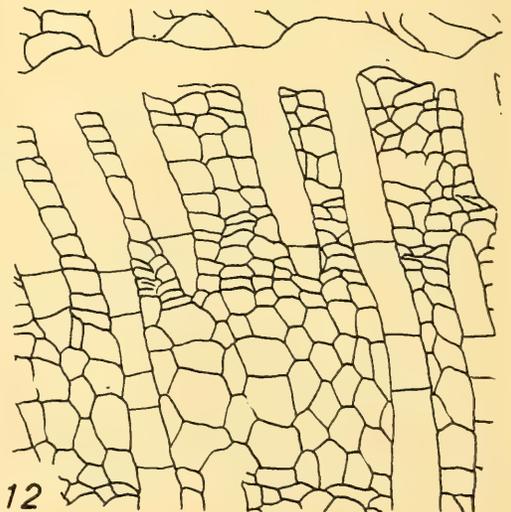
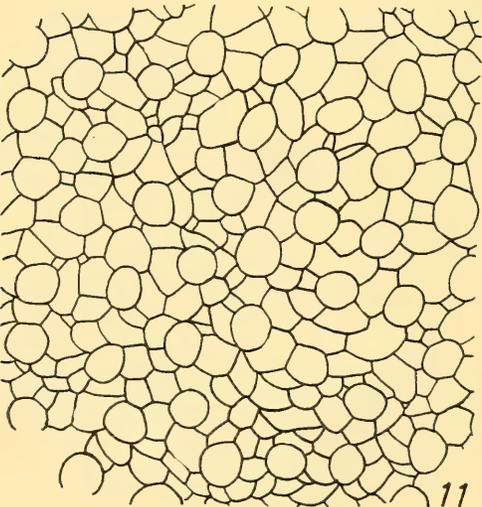
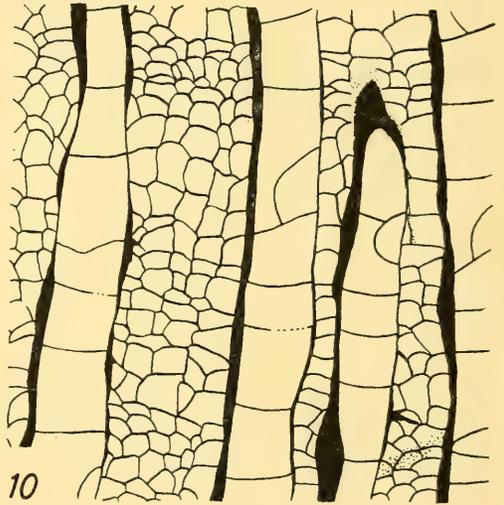
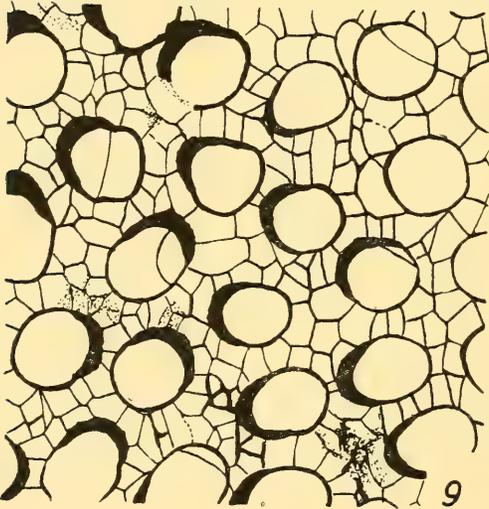
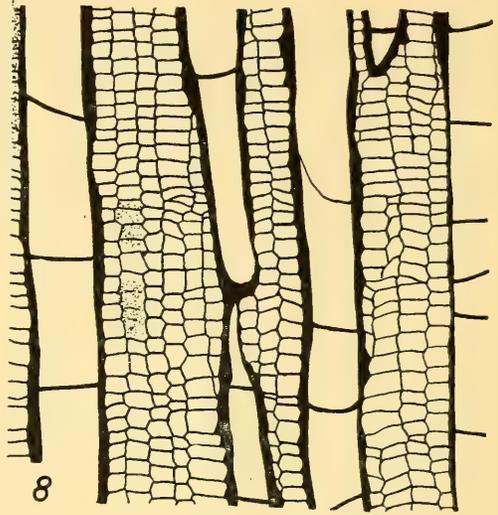
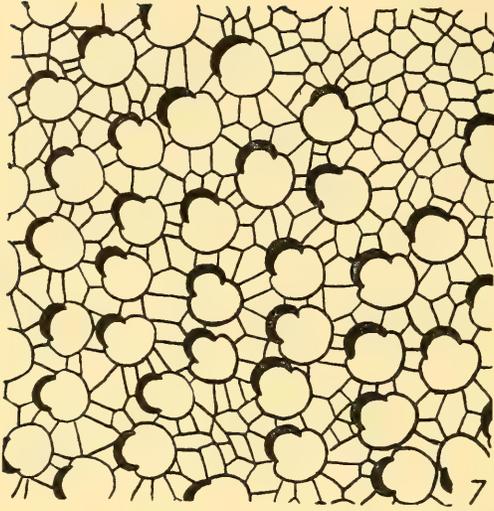
The zooecia are tubular, sub-circular in transverse section, and very slightly indented by the lunaria. The lunaria are not greatly thickened; they extend around one-third to nearly one-half of the circumference of each tube. Measurements of the size of average zooecia are: a, 0.39–0.44 mm.; b, 0.36–0.44 mm.; c, 0.1–0.22 mm.; d, 0.26–0.4 mm.; but both larger and smaller zooecia rarely occur. There are 17 to 19 zooecia in 7 sq. mm.

Text-figs. 1-2.—*Fistulipora vacuolata*, n. sp. Thin sections of the holotype,  $\times 20$ . 1. Tangential section, with part of a macula shown in the upper left hand corner. 2. Vertical section. (Slides 41184, 41185, Univ. W. Aust. Colln.)

Text-figs. 3-4.—*Fistulipora compacta*, n. sp. Thin sections of the holotype,  $\times 20$ . 3. Tangential section. 4. Vertical section. (Slides 41190, 41191, Univ. W. Aust. Colln.)

Text-figs. 5-6.—*Fistulipora wadei*, n. sp. Thin sections of the holotype,  $\times 20$ . 5. Tangential section; part of a macula is shown in the lower right hand corner. 6. Vertical section. (Slides 41179, 41180, Univ. W. Aust. Colln.)

All the text-figures were drawn with the aid of a *camera lucida*.



Thin, complete, straight or oblique diaphragms are abundant in the zooecial tubes; they are most usually spaced between 0.25 and 0.8 mm. apart, with from 6 to 9, and usually 7, in 3 mm. The zooecia are usually completely separated by thin walled vesicles, which are angular and very coarse; they occur most frequently in one, but may be in two or more, rows between adjacent zooecia, and are not modified in any way as the surface is approached.

FISTULIPORA CONICA, n. sp. Text-figs. 9, 10.

*Horizon and locality:* From strata in the lower 150' of Calceolispongia Stage of Wandagee Series, east limb of Syncline west of Coolkilya Pool, Minilya R. (holotype). Coll. H. Coley; and west limb of this syncline,  $\frac{1}{4}$  mile west of shale outcrop on north bank of Minilya R. (F 37592, Aust. Mus. Colln.). Coll. H. Coley.

*Holotype:* 22130, Univ. W. Aust. Colln.

*Massive* *Fistulipora*; *zooecia large, with strongly thickened lunaria, which slightly indent the tubes; diaphragms numerous; vesicular tissue coarse.*

The zoarium is massive and fairly large, the holotype being about 3.5 cm. high and about 5 cm. wide. The zooecial apertures are large and are prominent on the surface; where the surface is not weathered the lunaria form hood-like projections above the apertures and the surface between the apertures is smooth and solid, but slight weathering removes the lunaria and exposes the coarse vesicles which separate the zooecial tubes. Small maculae composed of aggregations of vesicles occur at distant and irregular intervals.

The zooecia are tubular, with rather thick walls, and they are only slightly indented by the lunaria; the lunaria vary in development in different parts of the one section; typically the lunarium extends around one-third to one-half of the circumference of the tube, and is strongly thickened, with the outer margin rather frilled, but in parts of the sections, as in the upper right hand corner of Text-figure 9, the lunaria are only very slightly thickened; the size of the tubes is also variable: a, 0.38–0.56 mm.; b, 0.32–0.57 mm.; c, 0.01–0.19 mm.; d, 0.27–0.43 mm.; large zooecia are more common than the smaller ones. In 7 sq. mm. there are from 12 to 16 zooecia. Diaphragms are numerous, usually they are placed between 0.25 and 0.95 mm. apart, with from 5 to 8 in 3 mm.; generally they are straight or only slightly concave, but very strongly curved diaphragms like large cystiphragms in appearance occur occasionally in many of the tubes. The zooecial tubes are separated by coarse vesicular tissue, there being usually one or two, rarely three, rows of vesicles between adjacent tubes.

FISTULIPORA GIGANTEA, n. sp. Text-figs. 11, 12.

*Horizon and locality:* Highest horizon with *Pseudogastriceras goochi* Teichert, 1942 (223), Linoproductus Stage of the Wandagee Series, about 8 chs. east of foot of Wandagee Hill, north-east of South-Western Gully. Coll. C. Teichert.

*Holotype:* 22127, Univ. W. Aust. Colln.

*Very large, massive* *Fistulipora*; *zooecia small, lunaria very weakly developed and not thickened; diaphragms numerous; vesicular tissue very coarse.*

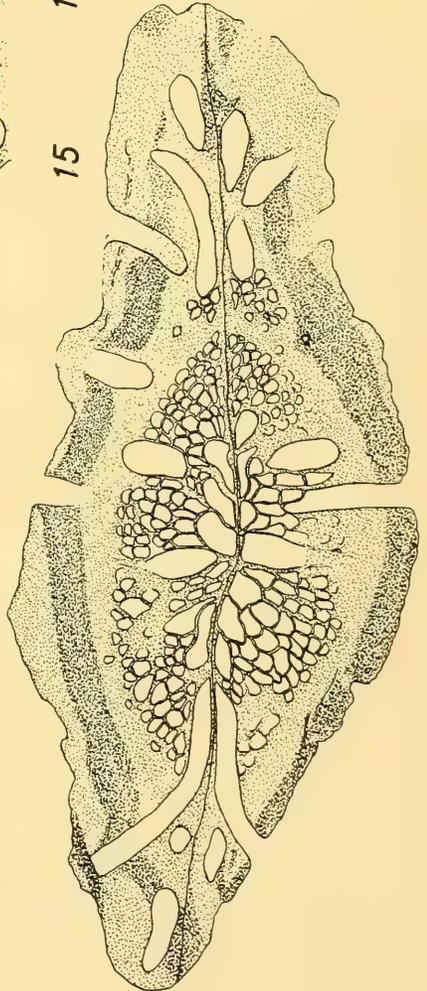
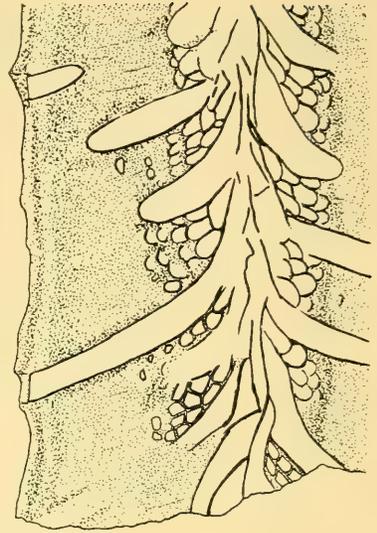
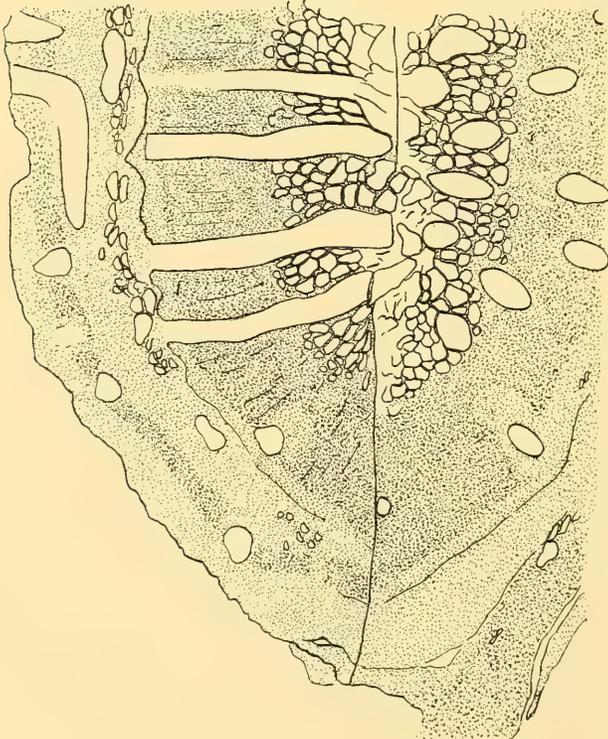
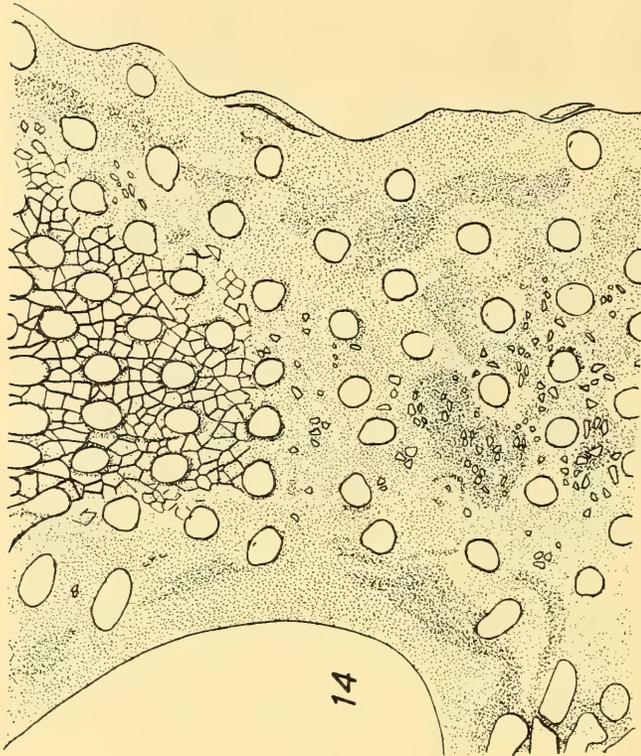
Zoarium massive and very large, the largest specimen being  $14 \times 9.5$  cm., and about 7 cm. high at the highest point; the colony is built up of a number of discontinuous layers of varying thickness, often distinct on weathered surfaces; the base is incrusting, and the upper surface is extremely irregular and is thrown up into a number of lobes; small, sometimes slightly raised maculae, about 2 mm. in diameter, and composed of aggregations of vesicles, occur on the surface, spaced about 5 to 8 mm. apart.

The zooecia are tubular, and are rounded to slightly oval in cross-section; lunaria are very poorly developed, occasionally the zooecial wall is curved to a slightly shorter

Text-figs. 7-8.—*Fistulipora crescens*, n. sp. Thin sections of the holotype,  $\times 20$ . 7. Tangential section; part of a macula is shown in the top right hand corner. 8. Vertical section. (Slides 41177, 41178, Univ. W. Aust. Colln.)

Text-figs. 9-10.—*Fistulipora conica*, n. sp. Thin sections of the holotype,  $\times 20$ . 9. Tangential section. 10. Vertical section. (Slides 41192, 41193, Univ. W. Aust. Colln.)

Text-figs. 11-12.—*Fistulipora gigantea*, n. sp. Thin sections of the holotype,  $\times 20$ . 11. Tangential section. 12. Vertical section. (Slides 41186, 41187, Univ. W. Aust. Colln.)



radius around one-quarter to one-third of the circumference, but there is no thickening, and the great majority of the tubes appear to be completely devoid of lunaria. The measurements of the zooecia are: a, 0.22–0.32 mm.; b, 0.22–0.33 mm.; c, 0.06–0.08 mm.; d, 0.14–0.17 mm.; about 29 to 33 zooecia occur in 7 sq. mm. The diaphragms are thin, placed 0.15 to 1.0 mm. apart, with 6 to 8 in 3 mm. The zooecia are completely separated by vesicular tissue; this is usually very coarse with angular vesicles often as large in cross-section as the zooecial tubes, but at irregular intervals, and particularly in the upper 1.5 to 2.0 mm. of a layer, the vesicles become much flatter and smaller in cross-section, giving quite a different appearance to both vertical and transverse sections.

Genus *HEXAGONELLA* Waagen and Wentzel, 1886.

*Hexagonella* Waagen and Wentzel, 1886, 909, 911; *Hexagonella* Waagen and Wentzel, Bassler, 1929, 50.

*Genotype: Hexagonella ramosa* Waagen and Wentzel, 1886.

*Range:* Permian.

*Zoarium bifoliate, internal structure Fistuliporoid, with lunaria usually absent, sometimes present; interzooecial spaces and maculae occupied by vesicular tissue, often replaced by dense tissue as the surface is approached; surface in some species divided by fine ridges into polygonal areas.*

Bifoliate *Fistuliporoids*, including species with broad frond-like zoaria, as well as species with narrow ribbon-like zoaria more like the genotype in external appearance, form an abundant and varied group in this fauna. Bassler (1929, 50) has suggested that the generic name *Hexagonella* should be retained for "bifoliate species with fistuliporoid internal structure save that lunaria are absent"; *Hexagonella turgida* Bassler from the Timor Permian shows slight lunaria at the surface, but there is no trace of lunaria in sections of this species or of the Indian species described by Waagen and Wentzel. In the majority of the Western Australian species lunaria are either absent or only poorly developed in sections, though they are in some of these forms distinct at the surface, but in some species, as in *H. undulata*, n. sp., they are more strongly developed and the zooecial tubes are bipetaloid in section. These bifoliate *Fistuliporoids* form such a distinct and compact group in this fauna, and there is such a gradual variation in the development of the lunarium in the different species, that it is here considered that the definition of *Hexagonella* should be extended to include species in which lunaria are developed.

In comparing sections cut parallel to the surface in these species, it is essential to deal with sections cut at about the same level in the zoarium, as there is a great deal of variation in structure from the centre to the surface; near the centre of the zoarium such sections pass through the mesial lamina and the recumbent part of the zooecial tubes adjoining it; above this, there is usually a zone in which the tubes are separated by vesicular tissue which is much coarser than that nearer the surface, and as the surface is approached, sections vary in appearance as the layers of dense and vesicular tissue are intersected; the development of the type of structure characteristic of a species is best studied, in tangential sections, in sections cut fairly close to the surface.

*Hexagonella australe* (Bretnall) is the only *Callytharra* species dealt with in this paper. The other species described are from the Barrabiddy shales, and the Wandagee and Nooncanbah Series.

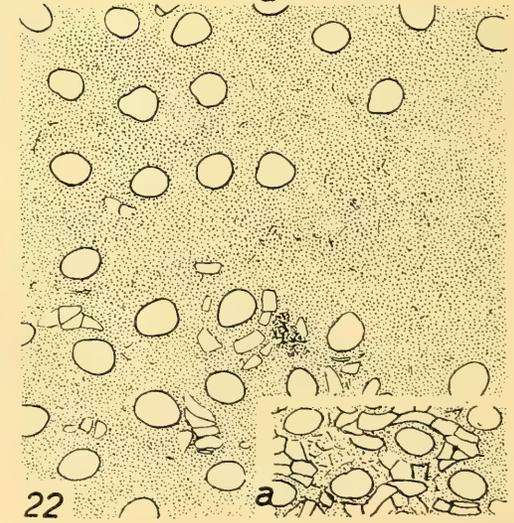
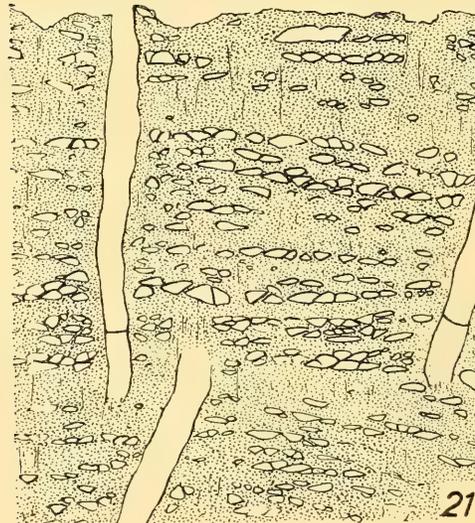
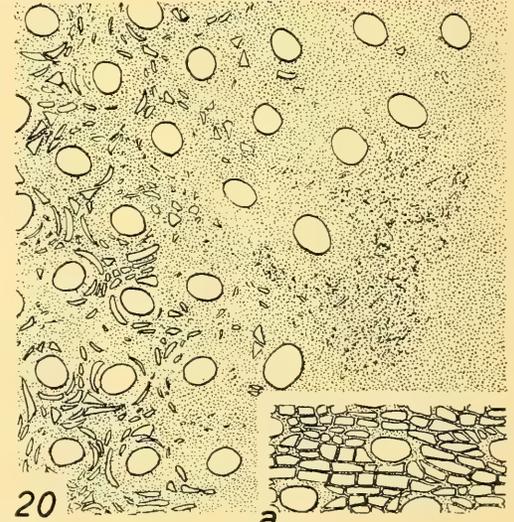
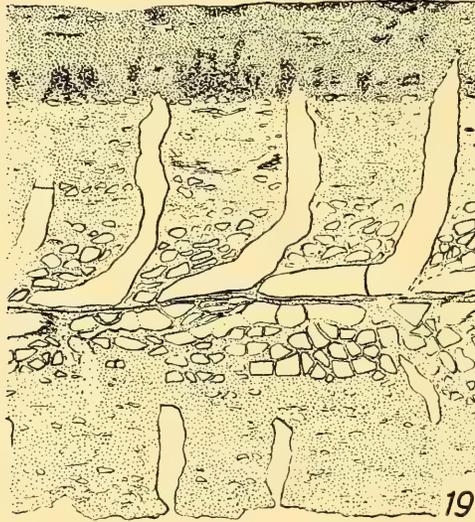
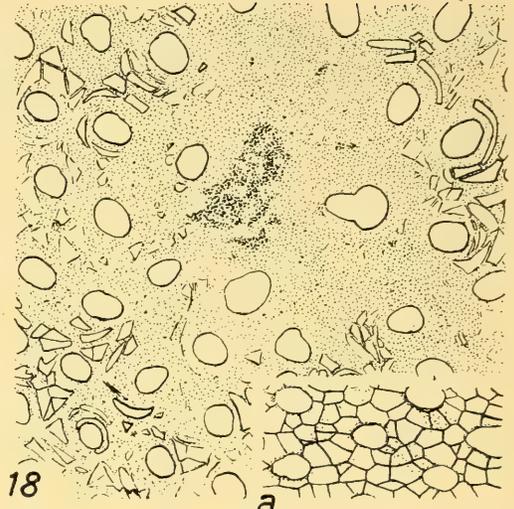
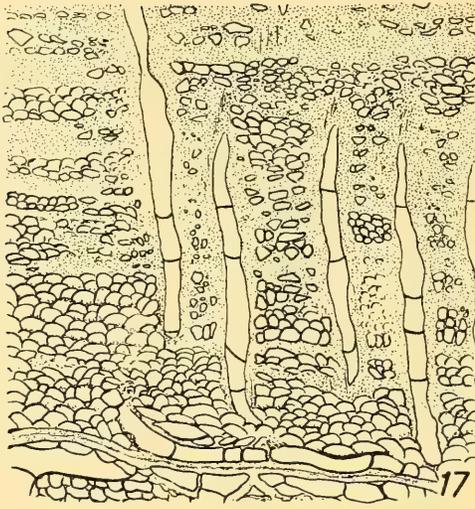
*HEXAGONELLA AUSTRALE* (Bretnall), 1926. Pl. iv, fig. 3; Text-figs. 13–16.

*Coscinium* (?) *australe* Bretnall, 1926, 25, Pl. i, fig. 5, Pl. ii, fig. 2.

*Horizon and locality:* Callytharra Stage, Fossil Hill, Wyndham R.

*Holotype:* 2/2405 G, W. Aust. Geol. Surv. Colln., figured by Bretnall, 1926, Pl. ii, fig. 2 (the magnification of this figure is  $\times 1\frac{3}{4}$  approx. and not  $\times 4$ , as stated by Bretnall).

Text-figs. 13–16.—*Hexagonella australe* (Bretnall). Thin sections of the holotype,  $\times 20$ . 13, 15. Transverse sections, 13 cut closer to the base of the zoarium, and showing the branches thickened by rejuvenation: the original branch at this level was also thicker in proportion to its width than at the level cut in 15. 14. Tangential section, passing obliquely from near the surface, where the zooecia are separated by dense tissue, to near the centre, where they are separated by vesicles. 16. Vertical section; the zoarium has been slightly shattered along the line of the mesial lamina.



a

a

a

*Narrow, ribbon-like Hexagonella, zoarium with lobate margins; zooecia small, sometimes with faint lunaria, without diaphragms; vesicular tissue fairly fine, replaced by dense tissue as the surface is approached.*

The zoarium is bifoliate, and consists of rather flattened branches, typically about 5 to 7 mm. in diameter, with lobate margins, and which branch in the same plane, and usually into three, at irregular intervals. There is no sign of any reticulation of the branches, and the "fenestrules" described by Bretnall apparently refer to the irregular spaces partly enclosed by the branches and their lobate margins. The lobes are opposite, and are placed about 6 mm. apart; they may develop into lateral branches. The zooecial apertures are arranged in rather irregular diagonal rows with about 12 zooecia in each; the apertures are surrounded by well-developed peristomes where they are well preserved, and some zooecia also show faint lunaria where about one-third of the circumference is curved to a slightly shorter radius. The zooecia are slightly oval, about 0.19 to 0.24 mm. long and 0.14 to 0.22 mm. wide; about 5 occur in 3 mm. longitudinally, and from 25 to 34 occur in a field of 7 sq. mm. The surface is weathered and between the apertures it is smooth, and a few rather widely separated hexagonellid ridges are shown; these are best shown near the lateral edges, where the surface is less weathered, but it is not possible to see how well developed these ridges were originally. The margins of the branches are not sharp; they are bordered by a narrow non-poriferous area, which is extended inwards for a short distance at the origin of each branch and lobe, and they are marked by a faint ridge formed by the edges of the mesial lamina. The base of the colony is not shown.

The zooecia are tubular, arising from each side of a distinct mesial lamina, and curving upwards to meet the surface at an angle of about 65° measured in the direction of growth. No diaphragms occur, but several zooecia are closed at the surface by a thin plate. Fairly fine vesicular tissue separates the zooecia near the mesial lamina, but about half-way to the surface this is replaced by dense tissue. In some sections of the holotype there is evidence of a second and third period of growth, with a recurrence of vesicular tissue and the development of new zooecia near the surface.

This species is a very much coarser form than *Hexagonella dendroidea* (Hudleston) 1883, from the Gascoyne River district.

HEXAGONELLA DENSA, n. sp. Pl. iv, fig. 2; Text-figs. 21-22a.

*Horizon and locality:* Lowest fossil horizon of the Barrabiddy Anticline, Barrabiddy shale series, about 3,500' feet below base of Wandagee Series, 20 chs. south of Barrabiddy Dam, Wandagee Station. (Same locality as *Pseudoschistoceras simile* Teichert, 1944.) Coll. Teichert and party.

*Holotype:* 22131, Univ. W. Aust. Colln.

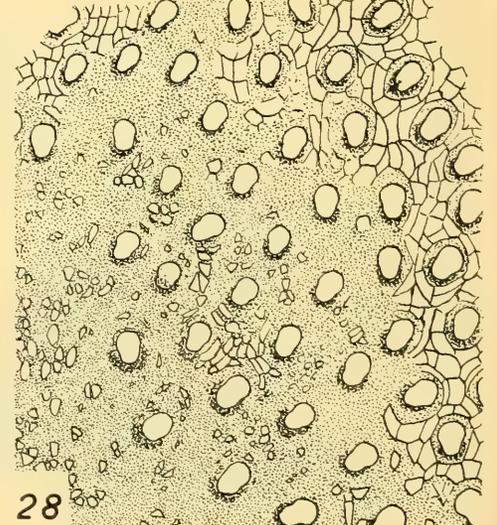
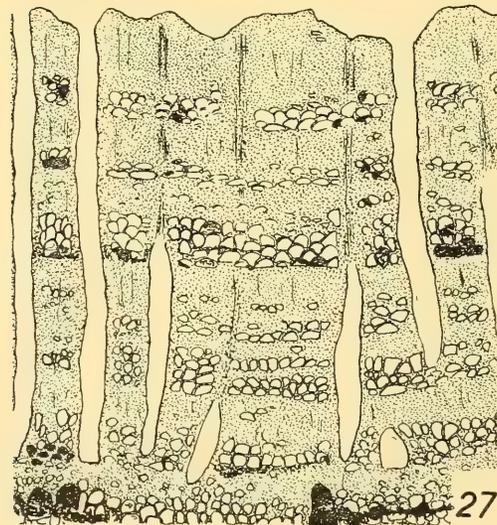
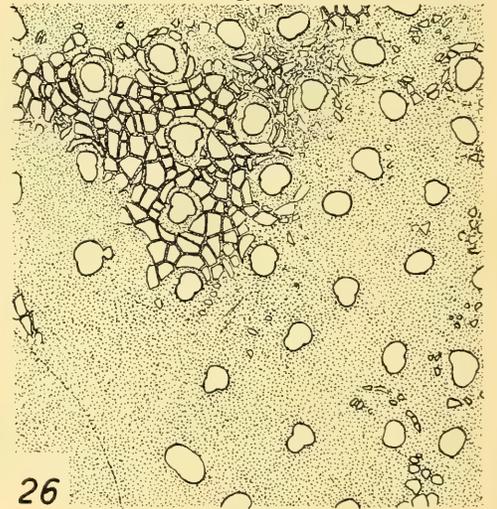
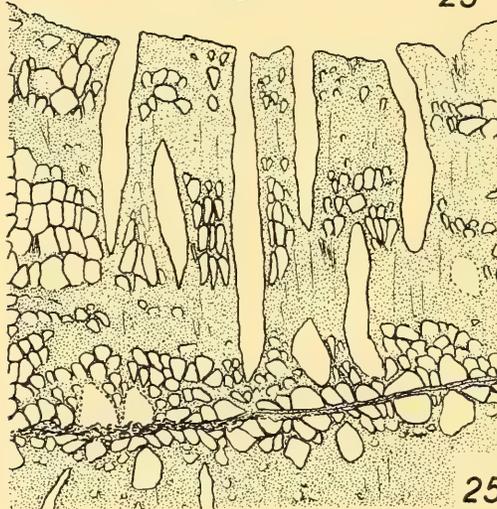
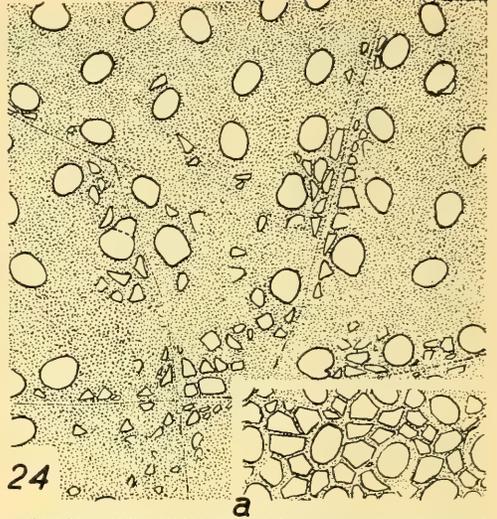
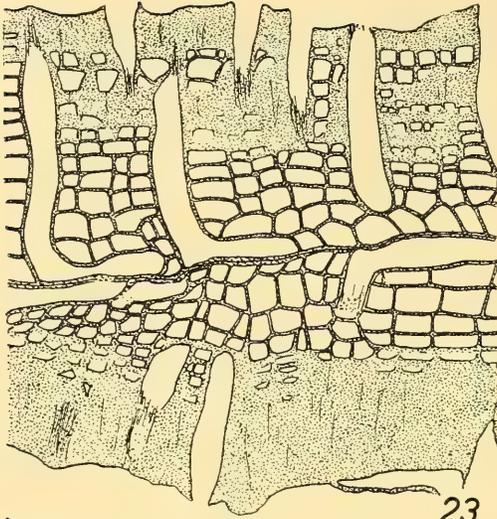
*Broad, frond-like Hexagonella, with large maculae composed of vesicles and dense tissue; zooecia small, sometimes with faint lunaria; diaphragms not numerous; inter-zooecial spaces filled by fine vesicles and dense tissue.*

The zoarium forms a broad, flattened bifoliate frond; the size of the holotype, which is an incomplete specimen, is 6 × 4.7 cm., and it is about 1 cm. thick at its thickest point. The surface is rather weathered and is marked by large, oval, solid maculae, which are made prominent by the weathering of the surfaces surrounding them; the centres of the maculae are spaced from 5 to 11 mm., generally about 8 mm. apart, and they are from 2 × 2.5 to 4 × 3 mm. in size; they are arranged, more or less regularly, in intersecting

Text-figs. 17-18a.—*Hexagonella plana*, n. sp. Thin sections of the holotype, × 20. 17. Vertical section. 18. Tangential section, cut in the outer part of the zoarium, with the spaces between the zooecia and the macula occupied by both dense tissue and vesicles. 18a. Tangential section, close to the centre of the zoarium, with the zooecia separated by vesicles. (Slides 41181, 41182, 41183, Univ. W. Aust. Colln.)

Text-figs. 19-20a.—*Hexagonella bifida*, n. sp. Thin sections of the holotype, × 20. 19. Vertical section. 20. Tangential section, cut in the outer part of the zoarium. 20a. Tangential section cut near the centre. (Slides 41194, 41195, 41196, Univ. W. Aust. Colln.)

Text-figs. 21-22a.—*Hexagonella densa*, n. sp. Thin sections of the holotype, × 20. 21. Transverse section. 22. Tangential section cut in the outer part of the zoarium. 22a. Tangential section cut near the centre. (Slides 41199, 41200, 41201, Univ. W. Aust. Colln.)



rows. The surface between the apertures is solid, and no hexagonellid ridges are now shown on it, although a few are shown in sections cut close to the surface.

The zooecia are tubular and are horizontal for only a short distance—about 0.8 mm.—on each side of the mesial lamina; they then bend sharply and meet the surface at almost a right angle. In a few tubes, especially in the slightly enlarged ones adjacent to the maculae, about one-third of the wall is curved to form a slight lunarium, which is rather thickened in some tubes. The tubes are usually about  $0.25 \times 0.2-0.24$  mm. in diameter. One or two thin, slightly concave diaphragms occur in each tube. There are 20 to 25 zooecia in 7 sq. mm., and the distance between the centres of adjacent tubes is 0.48 to 0.68 mm. The maculae and interzooecial spaces are solid at the surface, but are filled by vesicular tissue near the centre, and this vesicular tissue replaces the dense tissue between the zooecia and in the maculae at intervals throughout the zoarium. The vesicles are thick walled, angular in transverse section near the centre, and elongate-oval close to the surface, and they are flattened on their lower and curved on their upper surfaces in vertical section. Near the centre, 8 to 11 vesicles surround each zooecium, but they are coarser closer to the surface, with about 6 around each tube; one to three rows of vesicles occur between adjacent tubes. The mesial lamina is thin, with rather coarse medial tubuli.

HEXAGONELLA NALBIA, n. sp. Text-figs. 27, 28.

*Horizon and locality:* Middle part (approx. zones 7-8) of Linoproductus Stage of the Wandagee Series, Nalbia Paddock, about  $\frac{1}{4}$  mile east of where the road from Wandagee Woolshed to Middalya passes through the fence between Mungadan and Nalbia Paddocks. Coll. E. de C. Clarke and J. Lord.

*Holotype:* 22133, Univ. W. Aust. Colln.

*Broad, frond-like Hexagonella, with large, closely spaced maculae and prominent hexagonellid ridges; zooecia small, closely spaced; lunaria slight; diaphragms very rare; interzooecial spaces and maculae occupied by fine vesicles and dense tissue.*

The zoarium is a rather thick, flattened, bifoliate frond, the larger specimen, the holotype, measuring  $3.5 \times 3.0$  cm., and about 0.8 cm. thick. The maculae are large, prominent, numerous, and irregularly and closely spaced, and are very irregular in shape; they are very slightly depressed, and measure  $0.2 \times 0.2$  to  $0.4 \times 0.3$  mm., their centres being spaced 3.5 to 6 mm. apart. The zooecial apertures are 0.21 to  $0.24 \times 0.14$  to 0.21 mm. in diameter, the zooecia close to a macula being slightly larger; 32 to 38 zooecia occur in 7 sq. mm. Thin, closely spaced and irregularly grouped hexagonellid ridges occur on the surface.

In section, the zooecia are horizontal and wedge-shaped on each side of the mesial lamina, but they rapidly bend and pass upwards vertically to meet the surface at right angles; slight lunaria, occupying about one-half of the circumference and slightly indenting the tubes, are shown in some zooecia; very thin diaphragms occur only very rarely. The vesicular tissue which separates the zooecia in the central part of the zoarium consists of rather flattened, irregular vesicles, developed in zones separated by dense tissue throughout the zoarium; the dense tissue becomes progressively more important as the surface is approached; the vesicles occur generally in two or three

Text-figs. 23-24a.—*Hexagonella lineata*, n. sp. Thin sections of the holotype,  $\times 20$ . 23. Vertical section. 24. Tangential section, cut near the surface of the zoarium, showing part of a macula and some of the fine hexagonellid ridges, which are shown in sections only near the surface, and the zooecia separated by a few vesicles and by dense tissue. 24a. Tangential section cut deeper within the zoarium, in the zone in which the zooecia are separated by coarse, thick walled vesicles. (Slides AM 3583, 3584, Aust. Mus. Colln.)

Text-figs. 25-26.—*Hexagonella undulata*, n. sp. Thin sections of the holotype,  $\times 20$ . 25. Transverse section. 26. Tangential section, cut through a macula crossed by an hexagonellid ridge in the lower left-hand corner, and passing through the zone in which the zooecia are separated mainly by dense tissue to that in which coarse vesicles are developed. (Slides 41188, 41189, Univ. W. Aust. Colln.)

Text-figs. 27-28.—*Hexagonella nalbia*, n. sp. Thin sections of the holotype,  $\times 20$ . 27. Transverse section; the mesial lamina, along which the zoarium has been shattered, is at the level of the zooecia filled by dark material near the base of the figure. 28. Tangential section. (Slides 41197, 41198, Univ. W. Aust. Colln.)

rows between the zooecia, and from 6 to 8 vesicles surround each tube. The hexagonellid ridges are seen in sections cut near the surface as fine light lines separated by a row of darker granules.

HEXAGONELLA UNULATA, n. sp. Text-figs. 25, 26.

*Horizon and locality:* Lower part (zone 8) of Linoproductus Stage of the Wandagee Series; Coolkilya Paddock, 6 chs. north of a point 96 chs. west (along fence) of the south-east corner ("Quinnanie Corner") of Paddock. Coll. C. Teichert.

*Holotype:* 22128, Univ. W. Aust. Colln.

*Broad, frond-like Hexagonella, maculae large, slightly depressed; hexagonellid ridges well developed; zooecia small, with distinct thickened lunaria; no diaphragms; vesicular tissue coarse near the centre, finer and partly replaced by dense tissue near the surface.*

The zoarium is thin and bifoliate, the holotype is about  $4 \times 4$  cm. and up to about 6 mm., but generally about 4 mm., thick. Large, slightly depressed, irregularly shaped, solid maculae,  $3 \times 1.5$  to 2 mm. in diameter, and spaced with their centres 5 to 9 mm. apart, occur irregularly on the surface. Fine hexagonellid ridges are well developed, but do not form any regular pattern on the surface. The zooecial apertures are usually much enlarged by weathering at the surface, but in section they are oval to bipetaloid, usually with distinct thickened lunaria, which occupy about one-half of the circumference; their measurements are: a, 0.21–0.27 mm.; b, 0.17–0.22 mm.; c, 0.1–0.13 mm.; d, 0.13–0.16 mm. From 25 to 30 zooecia occur in 7 sq. mm. No diaphragms occur. Vesicular tissue between the zooecia is subordinate to dense tissue, but numerous angular vesicles, 8 to 10 surrounding each tube, occur between the zooecia in about two to six rows in the central part of the zoarium, and zones of vesicular tissue, usually finer than that at the centre, occur throughout the zoarium.

This species resembles *H. nalbia*, n. sp., which occurs on the same horizon, in its surface characters, except in the thickness of the zoarium, but is differentiated by the spacing of the tubes, and internally by the greater development of lunaria, and by the type of vesicular tissue.

HEXAGONELLA BIFIDA, n. sp. Text-figs. 19–20a.

*Horizon and locality:* Nooncanbah Series, just north of Hill C, Grant Ra., West Kimberley Division.

*Holotype:* 22132, Univ. W. Aust. Colln.

*Hexagonella with a broad, parallel-sided frond; zooecia without lunaria; diaphragms rare; interzooecial spaces and maculae occupied by fairly coarse vesicles, replaced by dense tissue near the surface.*

The zoarium is a broad, parallel-sided, flattened, bifurcating frond; the width of fully-developed branches is about 2.3 cm. to 2.7 cm., and the thickness of the branches about 2 to 3.5 mm.; two bifurcations of the frond, about 4.5 cm. apart, are shown in the holotype. Small, solid, oval to rounded maculae, up to about 4 mm. long and 1.5 to 3 mm. wide, occur irregularly but usually fairly closely spaced on the surface; they are level with the rest of the surface. No hexagonellid ridges are shown. No lunaria are developed, and the zooecial apertures are oval,  $0.21 \times 0.17$  to  $0.24 \times 0.22$  mm. in diameter; the zooecia bordering the maculae are usually slightly larger. The apertures are surrounded by distinct peristomes; from 22 to 26 apertures occur in 7 sq. mm. The zooecia are tubular, and are recumbent for a comparatively long distance (about 1 mm.) on each side of the thin, flexuous mesial lamina; they bend at varying angles, fairly sharply, to the surface. Slightly concave diaphragms occur in some of the tubes. The zooecia are separated by alternating layers of vesicular and dense tissue of varying thicknesses. The vesicles are coarse near the centre, and more flattened near the surface, where they are long and narrow in tangential section, with three to five rows separating adjacent zooecia.

HEXAGONELLA LINEATA, n. sp. Plate iv, fig. 4; Text-figs. 23, 24.

*Horizon and locality:* Nooncanbah Series, Mt. Marmion. Coll. H. Basedow.

*Holotype:* F 17567, Aust. Mus. Colln.

*Broad, frond-like Hexagonella, with numerous regularly placed maculae, and strong hexagonellid ridges; zooecia small, lunaria distinct at surface, rarely shown in sections; diaphragms rare; vesicular tissue very coarse, replaced by dense tissue near the surface.*

The zoarium is bifoliate, and forms thin, broad, folded fronds, up to  $3.5 \times 2.5$  cm. in size; the holotype is from about 3 to 4 mm. thick, but a second specimen (F 17569, Aust. Mus. Colln.), from the same locality, is only 1 to 2.5 mm. thick; apart from this difference in thickness, these specimens are identical in surface and internal structure. The edges of the frond are fairly sharp to rounded. The surface is divided up into irregular polygonal areas, 1.5 to 7.5 mm. across, by thin, slightly raised ridges, which are rapidly removed by weathering; small, oblong, solid maculae, about 1.5 mm. wide and 2.5 to 3.5 mm. long, occur usually where three or more ridges join; the maculae are arranged in intersecting rows, and are spaced 3 to 7 mm. apart, being rather further apart in the direction of their longer diameters than at right angles to them. The surface between the apertures is solid and coarsely granular where it is well preserved, but slight weathering exposes the vesicles which separate the zooecia internally. The zooecial apertures radiate from the maculae and are oval, and are surrounded by slight peristomes, separated and raised at one end to form distinct lunaria occupying about one-third of the circumference of each aperture, and curved to a very slightly shorter radius than the rest of the tube wall; in sections this lunarium can be seen only in a very occasional tube, and the tubes are oval and rather thick walled, 0.21 to 0.25 mm. long by 0.16 to 0.21 mm. wide. The tubes are horizontal for about 0.8 mm. on each side of the thin mesial lamina, and then bend at varying angles, but usually sharply, towards the surface; about 33 to 36 tubes occur in 7 sq. mm. Diaphragms occur only in a few tubes. The dense tissue which separates the zooecia at the surface forms a layer of varying thickness, but usually 0.3 to 0.65 mm. thick, and within this the spaces between the zooecia, and the maculae, are occupied by vesicular tissue; the vesicles are very coarse and thin walled near the centre of the zoarium, but become flatter and thicker walled as the dense tissue is approached; they are angular in transverse section, and occur in one or two, rarely three, rows between the zooecia, with 6 to 9 vesicles around each tube.

HEXAGONELLA PLANA, n. sp. Text-figs. 17-18a.

*Horizon and locality:* Highest fossil horizon of Nooncanbah Series, south-east side of Mt. Marmion, near foot of slope. Coll. C. Teichert.

*Holotype:* 22125, Univ. W. Aust. Colln.

*Broad, frond-like Hexagonella, with regularly arranged, small, slightly depressed, solid maculae; zooecia small, lunaria poorly developed; diaphragms fairly numerous; vesicular tissue fine, replaced by dense tissue near the surface.*

The zoarium is a broad, flattened bifoliate frond; along one edge the surface is raised to form small fronds at right angles to the main one; the size of the holotype, which is an incomplete specimen, is  $3.5 \times 4.5$  cm., and its thickness is up to 8 mm. Small, solid, slightly depressed maculae occur in intersecting rows on the surface; they are about 1.5 mm. in diameter, and their centres are 4.5 to 6 mm. apart. The surface between the apertures is solid; the zooecial apertures are oval, and in section poorly developed lunaria, occupying rather more than one-half of the circumference, are shown in some of the tubes; measurements of zooecia in sections are: a, 0.21-0.25 mm.; b, 0.16-0.21 mm.; c, 0.13-0.14 mm.; d, 0.16-0.19 mm.; 26 to 32 zooecia occur in 7 sq. mm., the distance between the centres of adjacent zooecia being 0.41 to 0.55 mm. The zooecia are horizontal for a short distance on each side of the mesial lamina, and then bend sharply until they are almost vertical. From one to five rather thick, slightly concave, irregularly spaced diaphragms occur in each tube. The zooecia are separated near the centre of the zoarium by thick walled, flattened vesicles; 9 to 11 vesicles surround each tube, and two to three rows occur between the zooecia; dense tissue intermittently replaces the vesicles, and almost completely replaces them near the surface. The mesial lamina is thin and fairly straight, with fine median tubuli. No hexagonellid ridges are developed.

## Order CRYPTOSTOMATA Vine.

## Family SULCORETEPORIDAE Bassler.

## Genus SULCORETEPORA d'Orbigny, 1849.

*Sulcoretepora* d'Orbigny, 1849, 501; *Sulcoretepora* d'Orbigny, McNair, 1937, 137.

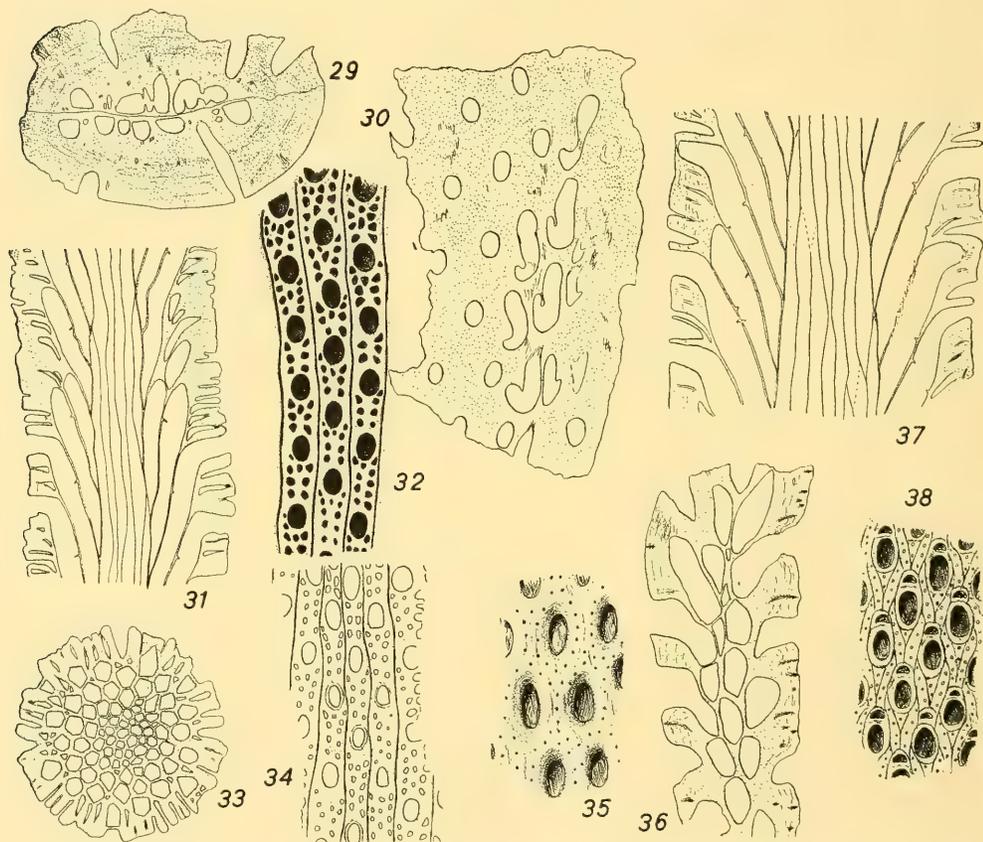
"SULCORETEPORA" *meridianus* (Etheridge) 1926. Pl. iv, fig. 6; Text-figs. 29, 30.

*Sulcoretepora* (?) *meridianus* Etheridge, 1926, in Bretnall, 19, Pl. i, fig. 9; [?] *Sulcoretepora meridianus* Etheridge, Hosking, 1931, 15.

*Horizon and locality*: Nooncanbah Series, Mt. Marmion (see p. 142).

*Holotype*: Specimen 15 on 10930a, W. Aust. Geol. Surv. Colln.

*Zoarium* a bifoliate, flattened stipe; zooecial apertures oval, in six longitudinal rows, increasing to eight before bifurcation, and in regular diagonal rows; zooecia with long



Text-figs. 29-30.—"*Sulcoretepora*" *meridianus* (Etheridge). Thin sections of specimen 15 on 10930b, W. Aust. G.S. Colln.,  $\times 20$ . 29. Transverse section. 30. Oblique tangential section, showing along the centre the hook-shaped form of the zooecia in sections cut parallel to the surface.

Text-figs. 31-34.—*Streblotrypa marmionensis* Etheridge. 31, 33, 34. Thin sections of specimens (Slides 41205-7, Univ. W. Aust. Colln.) from Mt. Marmion,  $\times 20$ . 31. Vertical section, showing the small hemisepta. 33. Transverse section. 34. Tangential section. 32. Surface of a specimen from Mt. Marmion (on 10930, W. Aust., G.S. Colln.),  $\times 20$ , showing a great deal of variation in the number and arrangement of the mesopore pits below the apertures.

Text-figs. 35-36.—*Rhombopora multigranulata* Bretnall. 35. Surface of the holotype,  $\times 20$ , to show the development of the acanthopores. 36. Vertical section of a paratype (3 on 10930a, W. Aust. G.S. Colln., from Mt. Marmion).

Text-figs. 37-38.—*Streblotrypa etheridgei* Bretnall. 37. Vertical section of a specimen from Mt. Marmion (on 10930, W. Aust. G.S. Colln.),  $\times 20$ , showing both inferior and superior hemisepta in the zooecia. 38. Surface of the holotype,  $\times 20$ .

*vestibules; recumbent part of zooecia hook-shaped; interspaces occupied by dense tissue with a few small vesicles.*

The zoarium is bifoliate, consisting of a flattened stipe about 1.74 to 1.95 mm. in width and about 0.95 to 1.1 mm. in thickness at its thickest part. The holotype is about 2 cm. long, and in this distance, three branches are given off at an angle of about 30° on one side of the stem, successive branches being 9.5 to 11 mm. apart; the specimen cannot be freed from the matrix sufficiently to show whether branches are given off alternately with these on the other side of the zoarium, but the arrangements of the apertures suggests that they are. Another specimen is 14 mm. long, and does not branch in that distance. The branches have a non-celluliferous margin about 0.25 mm. wide on each side, and a slight ridge along each edge marks the position of the ends of the mesial lamina; the edges are not very sharp, and one is slightly more rounded than the other. The apertures are oval, 0.16 × 0.11 mm. in diameter; the distance between the centres of successive apertures is 0.46 to 0.57 mm. on the parts of the branches where they are regularly arranged, and 20 to 21 occur in 10 mm. The peristomes are slight at the anterior ends of the apertures, but are raised at the posterior ends so that they form a slight hood over the aperture, but this part is not curved to a shorter radius than the rest of the peristome. There are normally six fairly well defined longitudinal rows of zooecia, increasing to about eight before bifurcation; the apertures are also arranged in diagonal rows. The surface between the rows of apertures is solid and finely granular.

Internally, the central part of the zoarium containing the cells comprises only one-quarter of its total width, the vestibules being three times as long as the depth of the cells. The interzooecial spaces are occupied by dense tissue, with a few small vesicles, developed in the inner part of the vestibular area and between the cells. The recumbent part of the zooecia appears hook-shaped in sections cut parallel to the surface (Text-fig. 30), and the zooecia are not separated by longitudinal plates; the mesial lamina is thin.

The internal structure, and especially the hook-shaped zooecia, in this species clearly separate it from *Sulcoretopora*, which it closely resembles externally. As only a limited amount of material, in which the internal structure was not best preserved, was available for the revision of this species, and since a number of new species resembling *Sulcoretopora* externally, and with different types of internal structure, occur in the Permian of Western Australia, definition of a new family and genus for the group to which "*S.*" *meridianus* belongs is left until all these *Sulcoretopora*-like forms are studied together and described; but because it would not be possible to recognize "*S.*" *meridianus* from the original description and figure, it is revised here to complete the description of the new species whose descriptions were published by Bretnall.

Hosking (1931, 15) has recorded this species from the Callytharra Series of the Wooramel River district, but did not figure specimens from this locality; I have been unable to find any specimens of "*S.*" *meridianus* in the material from the Callytharra available to me.

#### Genus GONIOCLADIA Etheridge, 1876.

*Goniocladia* Etheridge, 1876, 522; *Goniocladia* Etheridge, Bassler, 1929, 88; Moore, 1929b, 154. *Homonym: Carinella* Etheridge, 1873.

*Genotype: Carinella cellulifera* Etheridge, 1873.

*Range:* Carboniferous to Permian.

*Zoarium* infundibuliform, celluliferous on the outer surface, composed of anastomosing branches; branches bifoliate, dividing in a plane at right angles to the mesial lamina, and enclosing polygonal fenestrules, whose size and shape are characteristic for each species; internal structure as in *Ramipora*.

#### GONIOCLADIA TIMORENSIS Bassler, 1929. Pl. v, fig. 8.

*Goniocladia timorensis* Bassler, 1929, 89, Pl. cclxvii (23), figs. 8-15.

Two specimens (2757e, f, Univ. W. Aust. Colln.), agreeing with the description and figures given for this species by Bassler, occur in material from the Nooncanbah Series,

9 miles east-north-east from Trig. Stn. G 2, St. George's Ra.; the holotype of the species is from the Basleo Beds at Basleo, Timor. In the specimen figured here, the base of the colony, giving off three strong branches which divide to give rise to the fenestrate colony, is preserved.

Although other species of *Goniocladia* occur at this and other localities in the Nooncanbah Series—there is a second specimen, of a coarser species, on the same piece of limestone as the figured specimen—there is not sufficient material available at present for their description.

Family FENESTRELLINIDAE Bassler.

Genus FENESTRELLINA d'Orbigny, 1849.

Two species of *Fenestrellina* which were originally described from the Wayland Shale of the Graham Formation (Upper Pennsylvanian) of North-Central Texas, were recorded (as *Fenestella pectinis* Moore, 1929—Commonw. Palaeont. Colln., F 793-794—and *F. spinulifera* Moore, 1929—Commonw. Palaeont. Colln., F 782-792) by Raggatt (1936, 128) from the Callytharra Series at Callytharra Springs on the Wooramel River. These specimens have been re-examined and are described here. Identity with the American species is not confirmed, the specimens previously recorded as *Fenestella pectinis* being here identified as *Fenestrellina horologia* (Bretnall) and *Minitya* sp. cf. *M. duplaris* Crockford, and those recorded as *Fenestella spinulifera* Moore are, with additional specimens, described as *Fenestrellina affluensa* (Bretnall), and *F. chapmani*, n. sp., *F. sparsigemmata*, n. sp., *F. alia*, n. sp., and *Minitya amplia*, n. sp.

FENESTRELLINA HOROLOGIA (Bretnall), 1926.

*Fenestella pectinis* Moore (*partim*), Chapman, in Raggatt, 1936, 128; [*non*] *F. pectinis* Moore, 1929, 18, Pl. ii, figs. 8-10; *Fenestella horologia* Bretnall, 1926, 15, Pl. i, fig. 6; *Fenestrellina horologia* (Bretnall), Crockford, 1944, 189, Pl. i, fig. 1, Pl. ii, fig. A.

*Horizon and locality*: Callytharra Stage, west of Callytharra, Wooramel R.

*Specimen*: F 793, Commonw. Palaeont. Colln.

This specimen is a coarser form, with more widely spaced zooecia and nodes, than *Fenestrellina pectinis*, and should be referred to *F. horologia*.

FENESTRELLINA AFFLUENSA (Bretnall), 1926. Pl. iv, fig. 10.

*Fenestella spinulifera* Moore, (*partim*), Chapman, in Raggatt, 1936, 128; [*non*] *F. spinulifera* Moore, 1929, 20, Pl. iii, figs. 3-5; *Fenestella affluensa* Bretnall, 1926, 16, Pl. i, fig. 8; *Fenestrellina affluensa* (Bretnall), Crockford, 1944, 188, Pl. i, fig. 6.

*Horizon and locality*: Callytharra Stage, west of Callytharra, Wooramel R.

*Specimens*: F 782-784, Commonw. Palaeont. Colln.

These three specimens of this species are more heavily calcified and are also better preserved than the holotype, which is from the Gascoyne River district (probably from the Callytharra Series, see p. 142). The heavy calcification makes for some differences in the appearance of the specimens—in the broader and thicker branches, and the wider dissepiments and shorter fenestrules—but the spacing and arrangement of the nodes and apertures, and of the branches and fenestrules, are as in the holotype.

FENESTRELLINA CHAPMANI, n. sp. Pl. iv, fig. 5.

*Fenestella spinulifera* Moore, (*partim*), Chapman, in Raggatt, 1936, 128; [*non*] *F. spinulifera* Moore, 1929, 20, Pl. iii, figs. 3-5.

*Horizon and locality*: Callytharra Series, west of Callytharra (holotype), and below Callytharra, Wooramel R.

*Specimens*: F 788-91, 801, Commonw. Palaeont. Colln. *Holotype*: F 788.

*Very coarse Fenestrellina, with large, widely spaced apertures, and very large, distant nodes.*

The zoarium is fenestrate; the branches are coarse, 0.54 to 0.76 mm. in width, with 8 to 9 in 10 mm. There is a slight median carina, with large, blunt nodes, developed from 0.73 to 2.1 mm. (generally between 0.85 and 1.4 mm.) apart; these nodes attain a height of up to 0.4 mm., and are up to 0.33 mm. in diameter at the top. The zooecia are

in two rows, increasing to three immediately before bifurcation; the apertures are large, 0.16 mm. in diameter, and are surrounded by thin, slightly raised peristomes. The distance between the centres of successive apertures is 0.36 to 0.5 mm., and there are 4 to 8, usually 5, apertures to a fenestrule, with about 25 in 10 mm. The fenestrules are 1.17 to 2.46 mm. in length and 0.54 to 0.95 mm. wide; there are 4 to 5 fenestrules in 10 mm. vertically. The dissepiments are 0.33 to 0.68 mm. wide. The whole of the celluliferous surface is covered by very fine granules and striae. On the reverse surface both branches and dissepiments are finely granular, with occasional coarse granules developed: the thickness of the branches is 0.65 to 1.0 mm.

FENESTRELLINA SPARSIGEMMATA, n. sp. Pl. iv, fig. 9.

*Fenestella spinulifera* Moore, (*partim*), Chapman, 1936, 128; [*non*] *F. spinulifera* Moore, 1929, 20, Pl. iii, figs. 3-5.

*Horizon and locality*: Callytharra Series, west of Callytharra, Wooramel R.

*Holotype*: F 785, Commonw. Palaeont. Colln.

*Coarse Fenestrellina, with rounded fenestrules, 3 to 4 zoecia to a fenestrule, and large, very widely spaced nodes.*

The zoarium is fenestrate; the branches are broad, 0.6 to 0.68 mm. in width, with 10 to 10.5 in 10 mm. There is a slight median carina, with a single row of large, very widely spaced, blunt nodes, placed from 0.97 to 1.3 mm. apart; the nodes reach a diameter of up to  $0.33 \times 0.27$  mm. at the top and are up to 0.16 mm. high, but many of the nodes are much smaller. The zoecial apertures are in two rows, increasing to three just before bifurcation; they are round, 0.17 mm. in diameter; the distance between the centres of successive apertures is from 0.36 to 0.43 mm., and there are 3 to 4 apertures to a fenestrule, with about 25 in 10 mm. The fenestrules are rounded, about 0.72 mm. long and 0.29 to 0.48 mm. wide, with 7 to 7.5 in 10 mm.; the dissepiments are 0.72 to 0.76 mm. wide. On the reverse surface, both branches and dissepiments are rounded and smooth, and are of about the same thickness.

This species is differentiated from *Fenestrellina affluensa* (Bretnall) by the much wider spacing of its nodes.

FENESTRELLINA ALIA, n. sp. Pl. iv, fig. 8.

*Fenestella spinulifera* Moore, (*partim*), Chapman, 1936, 128; [*non*] *F. spinulifera* Moore, 1929, 20, Pl. iii, figs. 3-5.

*Horizon and locality*: Callytharra Series, west of Callytharra, Wooramel R.

*Specimens*: F 786-7, Commonw. Palaeont. Colln. *Holotype*: F 786.

*Coarse Fenestrellina, with 7.5 to 8 fenestrules in 10 mm., and 4 zoecia to a fenestrule; nodes very rarely developed.*

The zoarium is fenestrate; the branches are broad, 0.54 to 0.62 mm. wide, with 10 to 11 in 10 mm.; the zoecia are in two rows, separated by a slight, rounded median carina, on which small nodes are developed only very occasionally; the distance between the centres of successive apertures is 0.3 to 0.4 mm., and there are usually 4, rarely 3 or 5, zoecia to a fenestrule, with about 29 in 10 mm.; the apertures are small and rounded, 0.11 mm. in diameter, and are surrounded by slight peristomes. The fenestrules are oval, 0.62 to 1.1 mm. long and 0.22 to 0.5 mm. wide, with 7.5 to 8 in 10 mm.; the dissepiments are 0.43 to 0.62 mm. wide. On the reverse surface both branches and dissepiments are evenly rounded and smooth, and they are of about the same thickness, about 0.6 to 0.87 mm.

Genus MINILYA Crockford, 1944.

MINILYA AMPLIA, n. sp. Pl. iv, fig. 7.

*Fenestella spinulifera* Moore, (*partim*), Chapman, 1936, 128; [*non*] *F. spinulifera* Moore, 1929, 20, Pl. iii, figs. 3-5.

*Horizon and locality*: Callytharra Series, west of Callytharra, Wooramel R.

*Holotype*: F 792, Commonw. Palaeont. Colln.

*Coarse Minilya, with 7 fenestrules and 12 branches in 10 mm., 3 zoecia to a fenestrule, small nodes placed in two rows on the carina.*

The zoarium is fenestrate; the branches are about 0.48 mm. wide, with 12 in 10 mm.; the zooecia are in two rows, separated by a broad and poorly defined median carina, which bears two rows of small nodes placed 0.19 to 0.22 mm. apart, one node being placed adjacent to each zooecial aperture. The apertures are small and rounded, 0.11 mm. in diameter, and are surrounded by thin, high peristomes; the distance between the centres of successive apertures is 0.35 to 0.43 mm., with 3, very rarely 4, apertures to a fenestrule, and about 25.5 in 10 mm. The fenestrules are oval, but are very much indented at the sides by the projection into them of the zooecial apertures; they are 0.86 to 1.17 mm. (generally less than 0.95 mm.) long, 7 occurring in 10 mm., and are 0.31 to 0.36 mm. wide; the dissepiments are 0.28 to 0.36 mm. wide. On the reverse surface both branches and dissepiments are smooth and evenly rounded, and they are of about the same thickness.

This species most closely resembles *M. kukaensis* (Bassler), 1929, from the Amarassi Beds of Timor, but differs in having fewer zooecia to a fenestrule, and in the wider spacing of its apertures.

MINILYA sp. cf. *M. DUPLARIS* Crockford, 1944.

*Fenestella pectinis* Moore, (*partim*), Chapman, in Raggatt, 1936, 128; [*non*] *F. pectinis* Moore, 1929, 18, Pl. ii, figs. 8-10; cf. *Minilya duplaris* Crockford, 1944, 173, Pl. i, figs. 5, 7, Text-fig. 1 C, D.

Specimen: F 794, Commonw. Palaeont. Colln., from the Callytharra Series, west of Callytharra, Wooramel R.

This specimen is separated by the two rows of nodes on its carina from the other specimen identified previously with *Fenestella pectinis*. It is a very small fragment, two fenestrules long, and resembles *Minilya duplaris* in the arrangement of its zooecia and nodes; the apertures in this specimen, and in several similar fragments sorted from loose material from the same locality, are, however, pyriform, instead of rounded and stellate, and the branches are narrower, the fenestrules slightly longer, and the zooecia and nodes rather more widely spaced than in typical *M. duplaris*, to which species it can be most closely compared; although the differences shown appear to be constant in the specimens available, the material is insufficient for description.

GENUS PROTORETEPORA de Koninck, 1878.

PROTORETEPORA AMPLA (Lonsdale), 1844.

*Fenestella ampla* Lonsdale, 1844, 163; *Protoretetepora ampla* (Lonsdale), Crockford, 1941, 406, Pl. xix, fig. 4.

A single specimen, 22320, Univ. W. Aust. Colln., from the Nooncanbah Series, scarp 2 miles east of Christmas Ck. Homestead, West Kimberley district, belongs to the same species as specimens from Bundanoon and Rylstone in New South Wales (Crockford, 1941, 406; 1943, 266) referred to *P. ampla* (Lonsdale).

Family ACANTHOCLADIIDAE Zittel.

In the pinnate forms belonging to this family, the most important characters in the determination of species are: (1) the arrangement of the zooecial apertures, their distance apart and their arrangement in relation to lateral branches, (2) the spacing of the lateral branches, and to a less extent the angle at which they are given off, (3) the characters of the carina and the arrangement of the nodes (if present), (4) the arrangement of accessory pores, if present, (5) any special type of surface ornamentation, such as the replacement of the carina by a series of longitudinal ridges and furrows, (6) the shape of unweathered zooecial apertures—the apertures are very readily weathered and enlarged, and lose their distinctive shape, but the shape of perfect zooecial apertures is an important characteristic.

The width of both the midrib and the lateral branches, which may in turn be pinnate, are largely determined by their position in the colony, those near the base being very robust and often greatly thickened by deposits of granular calcium carbonate,

which may obliterate the apertures; these characters are, therefore, not of specific value.

Branching near the base of the colony apparently tends to be very irregular, and a number of small bases of *Penniretepora* up to about 5 mm. high, which occurred in material from the Callytharra, could only be referred tentatively to any species on the characters and spacing of the zooecia and nodes.

Genus PENNIRETEPORA d'Orbigny, 1849.

*Penniretepora* d'Orbigny, 1849, 501; *Penniretepora* d'Orbigny, Bassler, 1934, 20, 165; [non] *Penniretepora* d'Orbigny, 1850, 45; Homonym: *Acanthopora* Young and Young, 1875; Synonyms: *Glaucanome* Auctt. (not Goldfuss, 1826), *Pinnatopora* Vine, 1884.

*Genotype*: *Retepora pluma* Phillips, 1827.

*Range*: Upper Silurian to Permian.

*Zoarium pinnate, midrib and branches with two rows of zooecia, usually separated by a carina, with or without a single row of nodes; branches free; zooecia simple, rhomboidal.*

Species of *Penniretepora* are fairly abundant in the Callytharra, and several hundreds of fragments were separated from material weathered from the limey shales at two localities, west of Callytharra, and below Callytharra, on the Wooramel R. A few more complete specimens preserved on the surface of slabs of limestone and limey shales from these and other localities were used in the descriptions of the three species which are here named. One of these species was previously recorded from the Callytharra as *Pinnatopora trilineata* Meek var. *texana* Moore (Chapman, in Raggatt, 1936, 128). A number of other species were represented in the fragmentary material examined, but the specimens at present available are not good enough for descriptions of these species to be made. A small number of pinnate specimens show two distinct rows of nodes on the carina, paralleling the development of a similar group of species in the Fenestrellinidae.

In view of their abundance in the Callytharra and in the Permian Basleo Beds in Timor, it is surprising that no specimens at all of *Penniretepora* have so far been found in material from the Wandagee and Nooncanbah Series.

PENNIRETEPORA TRIPOROSA, n. sp. Pl. v, fig. 4; Text-fig. 49.

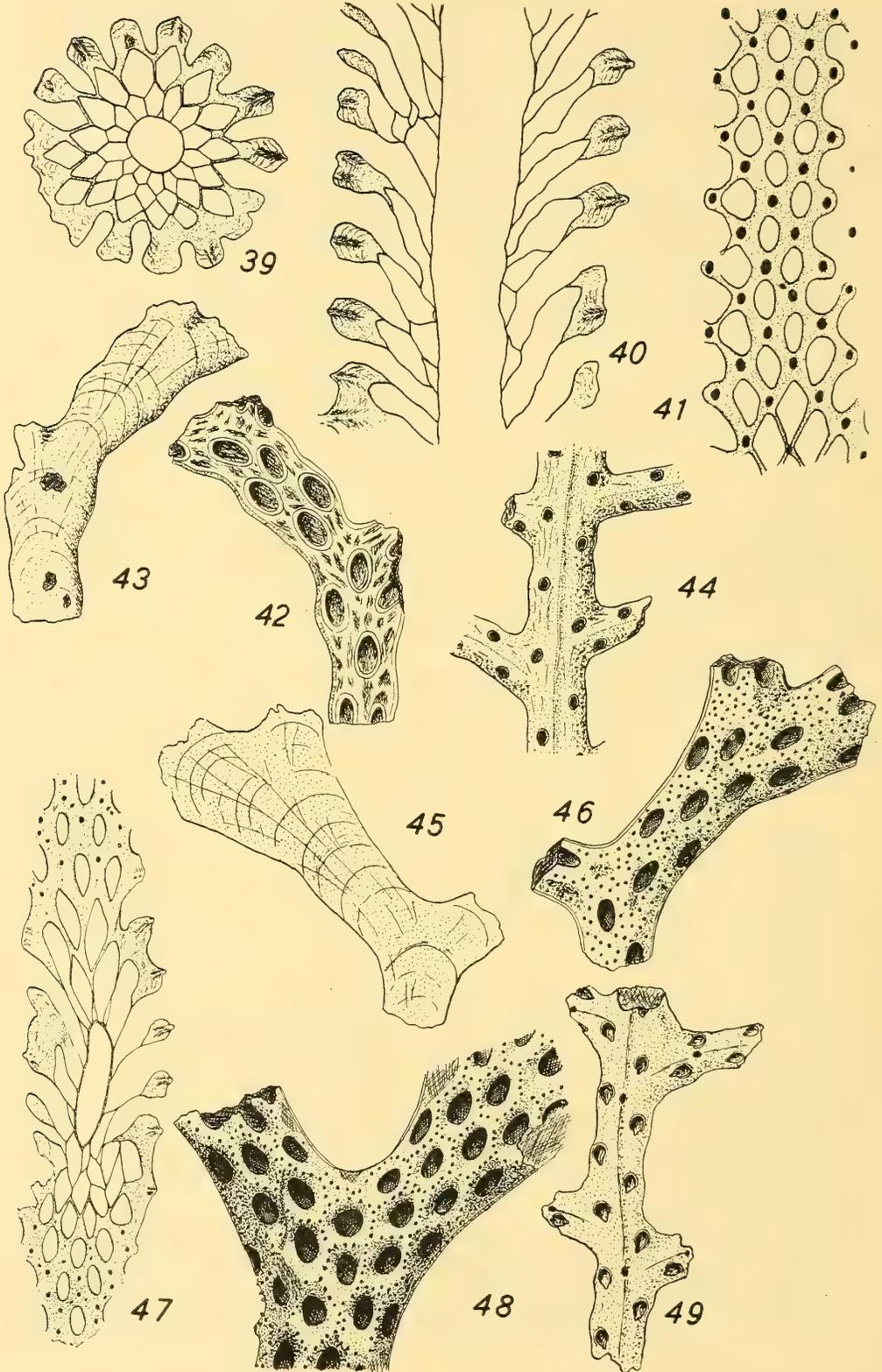
*Pinnatopora trilineata* var. *texana* Moore, Chapman, in Raggatt, 1936, 128; [non] *Pinnatopora trilineata* Meek var. *texana* Moore, 1929b, 126, Pl. xv, figs. 6-9.

*Horizon and locality*: Callytharra Series, west of Callytharra (*holotype*) and below Callytharra (F 792, Commonw. Palaeont. Colln.), Wooramel R.; Well  $\uparrow$  20, Daurie Ck., Gascoyne R. district (on 2/2404B, W. Aust. G.S. Colln.).

*Holotype*: F 795, Commonw. Palaeont. Colln.

*Fine Penniretepora, three zooecia between the origins of successive branches, slight carina with distant nodes.*

The zoarium is pinnate; the midrib is rather thin, 0.35 to 0.67 mm. wide, with alternating to almost opposite lateral branches, given off at an angle of 55° to 70°, and 0.27 to 0.43 mm. wide; the distance between the carinae of two successive branches on the same side of the midrib is 1.0 to 1.6 mm., and there are about 8 lateral branches on each side of the midrib in 10 mm. The zooecial apertures are in two rows on both the midrib and branches, and on the midrib there are three apertures between the points of origin of two successive branches. The apertures are pyriform, and when they are perfectly preserved nine short spines are shown projecting into each aperture; they are surrounded by thin, raised peristomes, and are up to 0.14  $\times$  0.1 mm. in diameter. There are about 24 apertures in 10 mm. on the midrib, where the distance between the centres of successive apertures is 0.36 to 0.49 mm.; on the lateral branches the spacing is rather closer, their centres being 0.33 to 0.4 mm. apart, and about 26.5 apertures occur here in 10 mm. Both midrib and branches bear a slight median carina, on which small nodes are developed; on the midrib the observed spacing of these, in specimens from the type locality, was 0.8 mm. to more than 1.6 mm., and in specimens from west of



Callytharra, in which the surface was better preserved, the spacing of the nodes was 0.6 to 2.1 mm., usually 0.95 to 1.6 mm., with an average of about 0.85 in 10 mm. The whole of the obverse surface is ornamented by oblique granular ridges and grooves about the apertures. On the reverse surface the midrib and branches are evenly rounded, and they are ornamented by granular longitudinal ridges and grooves.

This species from the Callytharra Stage differs from *Penniretepora trilineata* var. *texana* (Moore) in the much wider spacing of the pinnæ and in the spacing of its apertures; the arrangement of the apertures is similar in the two species, but *P. triporosa* has only 24 apertures in 10 mm. compared with 31 to 32 in *P. trilineata texana*; the type of carina and the presence of nodes also differentiate *P. triporosa*.

PENNIRETEPORA GRANULATÁ, n. sp. Pl. v, fig. 9; Text-fig. 44.

*Horizon and locality:* Callytharra Series, below Callytharra (holotype) and west of Callytharra (F 797, Commonw. Palaeont. Colln.), Wooramel R.

*Holotype:* F 800, Commonw. Palaeont. Colln.

*Fine* Penniretepora, with two zooecia between the origin of successive branches; slight carina marked by a row of fine granules, but without nodes.

The zoarium is pinnate; the midrib is 0.3 to 0.8 mm., typically about 0.55 mm. wide, with lateral branches 0.21 to 0.4 mm. wide, given off at angles of 50° to 85°, the angle varying considerably in any one specimen; only one lateral branch was observed to be pinnate, and this one showed a single branch directed towards the midrib and given off about 6 mm. from the point of origin of the lateral branch. About 10 lateral branches are given off on each side of the midrib in 10 mm., the distance between the carinae of two branches on the same side being from 0.82 to 1.35 mm., usually between 0.95 and 1.1 mm.; lateral branches on opposite sides of the midrib are alternating. The zooecial apertures are very small—about 0.08 mm. in diameter—and are surrounded by slight peristomes; when perfectly preserved they are stellate. There are two rows of apertures on both midrib and branches; on the midrib the zooecia are placed so that one aperture occurs at the point of origin of each lateral branch and one in the space between the branches. On the midrib there are about twenty apertures in 10 mm., the distance between the centres of successive apertures being 0.4 to 0.67 mm. The apertures are rather more closely spaced on the branches, 25 occurring in 10 mm., the distance between their centres being 0.36 to 0.44 mm. The carina forms a slight, straight or slightly sinuous ridge marked by a row of very fine granules along the centre of each branch; no nodes are developed. Both obverse and reverse surfaces are coarsely granular. When the reverse surface is slightly weathered it is marked by about ten strong longitudinal ridges and grooves on the midrib, and six on the branches.

PENNIRETEPORA FOSSATA, n. sp. Pl. v, fig. 6.

*Horizon and locality:* Callytharra Series, below Callytharra, Wooramel R.

*Holotype:* F 803, Commonw. Palaeont. Colln.

*Flexuous* Penniretepora, apertures large, three between the origins of successive branches; obverse and reverse surfaces ornamented by coarse ridges and grooves; carina replaced by usually three continuous ridges, no nodes developed.

The zoarium is pinnate; the midrib is flexuous, 0.47 to 0.63 mm. wide, giving off alternating lateral branches 0.35 to 0.55 mm. wide, spaced 1.1 to 1.7 mm. apart, with about 7.5 on each side of the midrib in 10 mm.; the lateral branches are given off at the

Text-figs. 39-41.—*Rhabdomeson mammillata* (Bretnall), × 20. 39. Transverse section. 40. Vertical section. 41. Tangential section, from specimens (Slides 41202-4, Univ. W. Aust. Colln.) from the Nooncanbah Series at Mt. Marmion.

Text-figs. 42-43.—*Streblocladia excavata*, n. sp. Obverse and reverse surfaces of the holotype, × 20.

Text-fig. 44.—*Penniretepora granulata*, n. sp. Obverse surface of the holotype, × 20.

Text-figs. 45-46.—*Rhombocladia minor*, n. sp. Reverse and obverse surfaces of the holotype, × 20.

Text-fig. 47.—*Rhabdomeson bispinosa*, n. sp. Oblique section of the holotype, × 20.

Text-fig. 48.—*Rhombocladia spinulifera*, n. sp. Obverse surface of the holotype, × 20.

Text-fig. 49.—*Penniretepora triporosa*, n. sp. Obverse surface of the holotype, × 20.

angles of convex curvature of the midrib at angles of 50° to 75°. In two specimens lateral branches give rise to pinnae at distances of 1 mm. and 1.2 mm. from the main stem. The apertures are circular, and are very large, 0.16 × 0.14 mm. in diameter, and when perfectly preserved they are surrounded by slight but distinct peristomes. The distance between the centres of successive apertures on the midrib is from 0.43 to 0.56 mm., and about 20.5 apertures occur in 10 mm.; there is one aperture placed opposite the origin of each lateral branch, and two, rarely one, in the space between two branches. On the lateral branches the apertures are rather more closely spaced—0.43 to 0.48 mm. apart, with about 23 in 10 mm. Both obverse and reverse surfaces are ornamented by strongly developed and coarse longitudinal ridges and grooves; on the obverse surface these are mostly discontinuous, and swirl around the zoecial apertures, but along the centre of the branch there are usually three, less often two, more continuous ridges which replace the carina. No nodes are developed.

*P. flexuosa* (Moore) (1930, 161), from the Graham Formation of Texas, is a generally similar species, but differs in its slightly smaller size and in possessing a very strongly defined carina.

In addition to this species a number of fragments of a similar species of *Penniretepora* occur in the material from below Callytharra; this second species has much smaller and more closely spaced apertures, which are stellate where they are perfectly preserved, and the lateral branches are given off from the midrib at much wider and more distant intervals, but the general appearance of the surface, here also ornamented by swirling ridges and grooves, is similar to *P. fossata*. A third associated species, similarly ornamented, is differentiated by the possession of a row of large, rather closely spaced nodes along the centre of the branches and has pyriform-stellate apertures. Neither of these species was represented by sufficiently well preserved material for description.

#### GENUS SEPTOPORA Prout, 1859.

*Genotype: Septopora cestriensis* Prout, 1859.

*Range:* Mississippian to Permian.

*Septopora* Prout, 1859, 448; *Septopora* Prout, Moore, 1929b, 129; Bassler, 1929, 87.  
*Synonym: Loculiporella* Frederiks, 1920.

"Zoarium a fenestrate, flabellate or leaf-like expansion; primary branches numerous, increasing by bifurcation or interpolation; the lateral branches unite with those from the adjacent primary branches; apertures in two rows on primary and lateral branches; reverse usually with fine striae and scattered dimorphic pores." (Nickles and Bassler, 1900, 41.)

Small fragmentary specimens of *Septopora*, all apparently belonging to the same species, are fairly abundant in material from the Callytharra Series; the genus is not so far known to occur in other Permian strata in Western Australia, although one species of the allied genus *Synocladia* occurs in the Cundlego Series.

#### SEPTOPORA ORNATA, n. sp. Pl. iv, fig. 11; Pl. v, fig. 3.

*Horizon and locality:* Callytharra Series, west of Callytharra (holotype) and below Callytharra (F 804, Commonw. Palaeont. Colln.), Wooramel R., and at Well ↑ 20, Daurie Ck., Gascoyne R. district (on 2/2404 B, W. Aust. G.S. Colln.).

*Holotype:* F 796, Commonw. Palaeont. Colln.

*Septopora* with thick branches joined by short, thick celluliferous dissepiments; usually 3 to 5 apertures on the main stem between successive lateral branches or dissepiments; accessory pores about equal in number to apertures on obverse surface, few on reverse; slight carina with large, distant nodes.

The zoarium is pinnate, composed of strong, thick branches 0.57 to 1.5 mm. wide, which give off lateral branches of variable width but narrower than the stem from which they arise. The branches are united by curved celluliferous dissepiments, 0.27 to 0.7 mm. wide, and separated by fenestrules 0.6 to 1.15 mm. long; in 10 mm., according to measurements taken on the one or two fenestrules closest to the main stem, the only ones preserved in any of the specimens examined; there are about 8 fenestrules and dissepiments

ments; occasional dissepiments are non-celluliferous for a very short distance in the centre. About 6.5 branches are given off in 10 mm. on each side of the main stem, the distance between the carinae of successive branches being 1.14 to 2.3 mm.; there are usually three to five, but up to seven, apertures between successive branches. The obverse surface is flattened; the zooecial apertures occur in two rows, separated by a very slight median carina, on both branches and dissepiments; the apertures are circular, about 0.14 to 0.16 mm. in diameter, and there are about 27.5 apertures in 10 mm., the distance between the centres of successive apertures being from 0.28 to 0.46 mm. The apertures are frequently laterally displaced—so that their arrangement appears somewhat haphazard in some specimens—by the presence of small circular “accessory pores” about 0.08 to 0.1 mm. in diameter, which are about as numerous as the apertures on the obverse surface; these pores are commonly placed so that one lies between each pair of apertures longitudinally. The carina bears a single row of large, irregularly spaced, blunt nodes placed from 0.63 to 1.9 mm. apart, there being about 8 nodes in 10 mm.; the whole of the obverse surface is ornamented by very fine longitudinal striae, or is smooth and finely granular. On the reverse surface the dissepiments are not as thick as the branches; when well preserved, the surface of both branches and dissepiments is finely granular and is ornamented by a few small tubercles; accessory pores occur on this surface but are not very numerous; where the surface is worn numerous strong longitudinal striae are shown.

Genus *SYNOCLADIA* King, 1849.

*Synocladia* King, 1849, 388.

*Genotype*: *Retepora virgulacea* Phillips, 1829.

*Range*: Upper Carboniferous to Permian.

“Zoarium as in *Septopora*, but branches stronger and with three or more rows of apertures, usually between elevated ridges” (Nickles and Bassler, 1900, 41).

*SYNOCLADIA SPINOSA*, n. sp. Pl. v, figs. 1, 2.

*Horizon and locality*: Lower part of Cundlego Series, 8 chs. from Stn. H 5 towards H 12 on traverse along south bank of Whitfield's Creek (a side branch of the Minilya R.), Washpool Paddock, Wandagee Station (holotype); same horizon and approximately same bed, 20 chs. from Stn. H 4 towards H 5, same traverse as above (22321, Univ. W. Aust. Colln.); approximately same horizon,  $\frac{1}{4}$  mile south-west of Cundlego Well, south bank of Minilya R., Coolkilya Paddock, Wandagee Station (22322, Univ. W. Aust. Colln.).

*Holotype*: 22134a, Univ. W. Aust. Colln.

*Synocladia* with broad, thick branches and short, curved, celluliferous dissepiments; apertures in 3 to 5 rows, 5 or 6 apertures to a fenestrule; “accessory pores” about equal in number to apertures on obverse surface; nodes not numerous, but very large, rows of zooecia not separated by carinae.

The zoarium is fenestrate, consisting of coarse, closely spaced, bifurcating branches joined by short, arched celluliferous dissepiments. In 10 mm. there are 4.5 to 6.5 branches horizontally and 5.5 fenestrules vertically. The branches are broad and thick, about 0.8 to 0.14 mm. in width, and are rather flattened on the celluliferous surface. The zooecial apertures are large, about 0.18 mm. in diameter, and were surrounded by thin, distinct peristomes; they occur usually in three to five rows on the branches, with about six rows immediately before bifurcation. The apertures are frequently displaced by the occurrence of the small, circular “accessory pores”, which are about 0.1 mm. in diameter, and about equal the apertures in number, and also by the occurrence of occasional, but very large acanthopores, which form blunt nodes up to 0.25 mm. wide at the top; these nodes occur irregularly; generally there is one, sometimes more, to a fenestrule, and they sometimes occur on the dissepiments. Five or six apertures in each row occur in the length of one fenestrule and one dissepiment, with about 29 apertures in 10 mm.; the distance between the centres of successive apertures is 0.3 to 0.4 mm. The lateral rows of apertures often open towards the fenestrules. The fenestrules are oval

to crescentic in shape, and measure from 0.65 to 1.75 mm. in their maximum width and from 0.75 to 1.15 mm. in their greatest length. The dissepiments are usually arched, but may be almost straight, and they are about 1.45 to 2.15 mm. wide; they show two, three, or four rows of apertures spaced about as closely as those on the branches, with about an equal number of "accessory pores" and occasional acanthopores. Etched specimens show the direction of growth of the zooecia on the dissepiments, pinnately from the branches on each side. In shape, the zooecia are parallel to the basal plate for comparatively a very short distance, then curve sharply to a long vestibule. On the reverse surface both branches and dissepiments are rounded, but the dissepiments are very much thinner than the branches; both are ornamented by fine, discontinuous, pitted grooves; "accessory pores" occur very infrequently on this surface; occasional coarse rootlets occur.

*Synocladia spinosa* resembles the genotype, *Synocladia virgulacea* Phillips, from the Permian of England, Germany and India, more closely than other described species of the genus, but is differentiated by the arrangement of the apertures, the absence of carinae, and the strongly developed nodes.

#### Family RHABDOMESONTIDAE Vine.

##### Genus RHABDOMESON Young and Young, 1874.

*Rhabdomeson* Young and Young, 1874, 337; *Rhabdomeson* Young and Young, Bassler, 1929, 69; Moore, 1929b, 141.

*Genotype*: *Millepora gracile* Phillips, 1841.

*Range*: Carboniferous to Permian.

*Zoarium* ramose, with slender cylindrical branches which give off lateral branches of the same size at intervals; zooecia rather short, diverging on all sides from a thin walled axial canal; zooecial walls thin in the axial region, strongly and evenly thickened in the peripheral region; diaphragms and hemisepta present or absent; acanthopores (sometimes of two sizes) well developed; apertures regularly arranged in longitudinal or in diagonal intersecting rows.

RHABDOMESON MAMMILLATA (Bretnall), 1926. Pl. v, fig. 14; Text-figs. 39-41.

*Rhombopora mammillata* Bretnall, 1926, 24, Pl. i, fig. 2; [*? non*] *Rhombopora mammillata* Bretnall, Hosking, 1931, 14; *Rhabdomeson shanse* Reed, 1934, 113, Pl. ii, fig. 3.

*Horizon and locality*: Nooncanbah Series, Mt. Marmion (see p. 142).

*Holotype*: Specimen 2 on 10930c, W. Aust. G.S. Colln.

*Coarse Rhabdomeson, axial canal large; zooecial apertures very regularly arranged in about 30 to 34 longitudinal rows, and in steeply intersecting diagonal rows; acanthopores large, one at each angle of each aperture.*

The zoarium is ramose, consisting of hollow cylindrical branches 1.8 to 2.15 mm. in width; branches are usually given off from the main stem at right angles, but occasionally it bifurcates to give two branches at right angles to each other. The apertures are oval, 0.2 to 0.27 mm. long and 0.13 to 0.17 mm. wide, and are arranged in very well marked longitudinal, transverse, and steeply intersecting diagonal rows. Longitudinally there are 23 to 24 apertures in 10 mm., the distance between the centres of successive apertures being 0.37 to 0.51 mm.; there are about 30 to 34 longitudinal rows of apertures. The interspaces are rounded, and are so arranged that they form well-marked diagonal ridges, cutting off rhombic areas containing the apertures. At each intersection of these ridges there is a single large, blunt acanthopore; no small acanthopores are developed.

The axial tube is rather thin walled, sub-circular in cross-section, and is from 0.36 to 0.6 mm. in diameter. It is not divided by diaphragms. The zooecia are short, and diverge from the axial tube at about 35° to 50°; the vestibules meet the surface at almost a right angle. The walls are strongly thickened in the cortical zone. Neither diaphragms nor hemisepta are developed. The acanthopores are large, blunt, and regularly placed at the angles of the apertures.

The figured specimen of *Rhabdomeson shanse* Reed, 1934, from the Anthracolithic Beds of Htam Sang in the Southern Shan States, is identical with this species; unfortunately the measurements given by Reed in the text do not in all cases correspond with those shown in the figure, but it is considered that the figured specimen at least should be referred to *R. mammillata* (Bretnall).

Bretnall records this species from the Callytharra Series at Fossil Hill, Wyndham River (F H a 2). There is now no specimen numbered "2" on any of Bretnall's material from this locality, and I have been unable to find any specimens of *R. mammillata* in material from the Callytharra either at this locality or from the Wooramel River district, where Hosking (1931, 14) has recorded its occurrence. It is possible that these records may refer to *Rhabdomeson bispinosa*, n. sp., in which the diagonal ridges are made prominent in weathered specimens, giving a similar "rhombic lattice" appearance.

RHABDOMESON BISPINOSA, n. sp. Text-fig. 47.

*Horizon and locality:* Callytharra Series, Fossil Hill, Wyndham R.

*Holotype:* On 2/2405 F, W. Aust. G.S. Colln.

*Fine Rhabdomeson, apertures regularly arranged in 14 to 16 longitudinal rows and in diagonal rows; acanthopores of two sizes, two large acanthopores in the longitudinal interspace between two apertures, small acanthopores not numerous.*

The zoarium is ramose; the branches are hollow, 0.95 to 1.1 mm. wide, the width of the axial tube being 0.2 to 0.27 mm. The apertures are oval, 0.17 to 0.24 mm. long by 0.08 to 0.11 mm. wide, and they are arranged in well-marked longitudinal and transverse and in steeply pitched diagonal rows. The distance between the centres of successive apertures in the same longitudinal row is 0.43 to 0.6 mm., and in each row there are 20 apertures in 10 mm.; there are about 14 to 16 rows of apertures. The interspaces are rounded, and as in *Rhabdomeson mammillata*, they are so arranged that they form well-marked diagonal ridges which cut off rhombic areas containing the apertures. There are two large acanthopores placed one above the other on the longitudinal interspace between two apertures, and in addition to these, a few small acanthopores (these are developed very close to the surface and are therefore not shown over most of the slide figured) occur on the ridges.

The axial tube is sub-circular in sections and is thin walled; it is not divided by diaphragms. The zooecia are short, and diverge from the axial tube at about 20°; the vestibules meet the surface at right angles. The walls are strongly thickened in the cortical zone, which is about 0.19 mm. wide. Neither diaphragms nor hemisepta are developed.

The arrangement of the acanthopores and the spacing of the apertures in this species is very similar to that in *Rhabdomeson consimile* Bassler, from the Basleo and Amarassi Beds of Timor; *R. consimile* is, however, of slightly larger size than this species, and has a larger axial tube, and differs in the angle at which the zooecia diverge from the axial tube and in possessing comparatively strong hemisepta; the acanthopores also appear to be larger and to originate deeper within the zoarium; because of these differences, especially the differences in internal structure, it seems best at present to consider these species distinct.

Genus RHOMBOPORA Meek, 1872.

*Rhombopora* Meek, 1872, 141; *Rhombopora* Meek, Ulrich, 1890, 402, 647; Moore, 1929, 137.

*Genotype:* *Rhombopora lepidodendroides* Meek, 1872.

*Range:* Ordovician to Permian.

*Zoarium ramose, branches without axial tube; zooecia long and tubular, otherwise as Rhabdomeson.*

RHOMBOPORA MULTIGRANULATA Bretnall, 1926. Pl. v, fig. 13; Text-figures 35, 36.

*Rhombopora multigranulata* Bretnall, 1926, 25, Pl. i, fig. 3; [*non*] *Rhombopora multigranulata* Bretnall, Hosking, 1931, 14, Pl. iv, fig. 4.

*Horizon and locality:* Nooncanbah Series, Mt. Marmion (see p. 142).

*Holotype*: Specimen 3 on 10930 c, W. Aust. G.S. Colln.: Bretnall lists specimen 3 on 10930 a as a paratype; there are two specimens labelled "3" on 10930 a, of which only the smaller belongs to this species.

*Fine Rhombopora, zooecial apertures long and oval, in 13 to 15 longitudinal rows; interspaces with numerous fine acanthopores.*

The zoarium is fine and ramose, with solid cylindrical branches, 0.92 to 1.1 mm. in diameter, which branch at intervals of 5 mm. or more; the angle between the branches after division is usually about 80°, but is up to 110°. The apertures are arranged in about 13 to 15 longitudinal rows, and in generally better marked diagonal rows; they are elliptical, 0.24 to 0.29 mm. long and 0.11 to 0.14 mm. wide; the distance between the centres of successive apertures in the same longitudinal row is 0.54 to 0.9 mm., and in each row there are about 14 apertures in 10 mm. The interspaces between the apertures are broad and rounded, and occasionally show slight longitudinal grooves. The acanthopores are small and numerous; they occur in one or two rows on the interspaces, and about 13 to 17 surround each aperture. No mesopores occur.

The zooecia are tubular and rather short, and are without hemisepta or diaphragms; the cortical zone is comparatively thick, comprising about 0.5 to 0.6 of the radius. The zooecia bend sharply from the axial to the cortical zone, and the vestibules usually meet the surface at almost a right angle.

The original description of this species does not apply very closely to the holotype or to other specimens which Bretnall labelled as conspecific with it. The species recorded and figured by Hosking from two localities in the Wooramel River district is a larger and much coarser form. *R. multigranulata* resembles in appearance *R. exigua* Ulrich 1890, with which Etheridge has compared it, but is a decidedly larger form.

#### Genus STREBLOTRYPA Ulrich, 1890.

*Streblotrypa* Ulrich, 1890, 403, 665; *Streblotrypa* Ulrich, Bassler, 1929, 66.

*Genotype*: *Streblotrypa nicklesi* Ulrich, 1884.

*Range*: Ordovician to Permian.

*Zoarium ramose, slender, solid; zooecia tubular, radiating from an imaginary axis at the centre, with the immature region long, or rarely from a linear axis, when the zooecia are shorter, or the central part of the zoarium may be occupied by a bundle of small tubes from which the zooecia diverge towards the surface; zooecial tubes usually with hemisepta; apertures elliptical, sometimes truncated at the posterior margin, arranged in regular longitudinal series; below the apertures, occupying the depressed front of the cell, are from one to twelve, or more, small "mesopore pits", separated by longitudinal ridges between the rows of zooecia, which are generally straight but occasionally flexuous; very small acanthopores, placed close to the apertures, present in some species.*

STREBLOTRYPA MARMIONENSIS Etheridge, 1926. Pl. v, figs. 10, 11; Text-figs. 31-34.

*Streblotrypa marmionensis* Etheridge, 1926, in Bretnall, 22, Pl. i, fig. 1, and Pl. ii, fig. 3; *Streblotrypa marmionensis* Etheridge, Hosking, 1931, 14, Pl. iv, fig. 1, and text-fig. 1; [?] *Streblotrypa germana* Bassler, 1929, 67, Pl. ccxxxix (15), figs. 6-10.

*Horizon and locality*: The holotype is from the Nooncanbah Series at Mt. Marmion; this species is one of the most widespread and abundant species in the collections from the Western Australian Permian, and it occurs abundantly at numerous localities in the Callytharra, the Barrabiddy shale series and the Cundlego, Wandagee and Nooncanbah series.

*Holotype*: F 17458, Aust. Mus. Colln. Of the paratypes listed by Bretnall, the following are here considered to be typical specimens of this species: "1" on 17539, 17540 (larger specimen only), 17541-2, 17547-51, 17559.

*Ramose Streblotrypa, with cylindrical branches with usually 16 to 20 rows of apertures, and with distinct areas of pits marked off by longitudinal ridges, and each containing 4 to 12 mesopore pits, posterior to the apertures.*

The zoarium is ramose, arising from an encrusting base; the branches are solid, and cylindrical, typically between 1.0 and 1.6 mm. wide, although occasionally slightly

finer or coarser specimens with the same zooecial characters occur. The zooecia are in about 15 to 24—usually between 16 and 20—longitudinal rows; the zooecial apertures are oval, or may be slightly truncated at the posterior end, and are 0.14 to 0.21 mm. long by 0.1 to 0.14 mm. wide; the distance between the centres of successive apertures is 0.32 to 0.68 mm., and about 22 occur in each row in 10 mm. The front of the cell is slightly depressed, and is perforated by usually from 4 to 12 mesopore pits. The development of ridges between the rows of zooecia varies considerably even in the one specimen; characteristically the rows of zooecia are separated by straight, strong ridges, but the ridges in some specimens are sinuous, and in some places the divisions between each row of mesopore pits in the areas below the apertures are so strongly developed that they form irregular ridges; in many specimens the ridges have been removed by weathering. Branching occurs at very irregular intervals—at times twice within 2 or 3 mm.; in other specimens it does not occur in more than 2 cm.; and the angle of branching varies greatly in any one specimen. The branches formed after division are frequently marked by a very strong development of the mesopore pits for the length of one or two zooecia after branching.

Internally this species shows the central bundle, occupying about one-quarter of the radius, of small parallel tubes characteristic of later members of the genus. The posterior wall of each zooecium contains the thick walled mesopore-like pits. Small inferior hemisepta are placed well within each zooecium. Superior hemisepta are not developed, and there are no diaphragms. In a number of specimens some apertures were closed by a thin, ornamented plate placed about midway down the vestibule, as shown in some of the tubes in the transverse section figured in Text-fig. 33. No acanthopores are shown. The zooecia bend sharply to the vestibule at an angle of 65° to 75°, and the vestibules and pits meet the surface at right angles. The width of the mature zone is about 0.3 mm.

Brettnall (1926) included in his paper descriptions of two species of *Streblotrypa*, *S. marmionensis* and *S. etheridgei* Brettnall. As has been pointed out by Hosking (1931, 15), the descriptions do not correspond well with the plates, and she suggested that in the explanation of Plate i the specific names had been interchanged. Both figures of *Streblotrypa* given on this plate by Brettnall are apparently diagrammatic illustrations of *S. marmionensis*, the longitudinal ridges of the specimen figured in Fig. 1 having been removed by weathering. Neither his Fig. 1 nor Fig. 7 could be a figure of the holotype of *S. etheridgei*.

There is considerable variation in specimens of *S. marmionensis* in the number and arrangement of the mesopore pits, and in the distance between the apertures. Although in some zoaria there are a more or less uniformly small or large number of pits, and the apertures are either fairly closely or fairly widely spaced, with short and broad or with long and narrow cell fronts, in the great majority of specimens these characters are extremely variable. The mesopore pits are of fairly constant size, except of course where they have been enlarged by weathering; there is an associated species of slightly larger size in which the pits are smaller, more numerous and thinner walled, and the base of the posterior wall of the zooecium which contains them is inclined at a greater angle to the surface (cf., *S. fasciculata* Bassler, 1929).

*Streblotrypa germana* Bassler, from the Permian Basleo and Amarassi Beds of Timor, is very probably identical with this species. According to the description, *S. germana* is a smaller form with slightly larger apertures, but the figured specimens are so very similar in size and appearance to specimens from Western Australia that they should probably be referred to the same species.

STREBLOTRYPA ETHERIDGEI Brettnall, 1926. Pl. iv, fig. 12; Text-figs. 37, 38.

*Streblotrypa etheridgei* Brettnall, 1926, 23, not Pl. i, fig. 7.

*Horizon and locality:* Nooncanbah Series, Mt. Marmion (holotype), Coll. H. Basedow; and Nooncanbah Series,  $\frac{1}{2}$  mile west of fence, Duchess Ridge, West Kimberley district.

*Holotype*: F 17550, Aust. Mus. Colln.; of other specimens listed by Bretnall as belonging to this species, specimen 5 on 10930 c, W. Aust. G.S. Colln., belongs here, but specimen 5 on F 17555, Aust. Mus. Colln., does not belong to this species, and there is now no specimen labelled "5" on F 17554, Aust. Mus. Colln., nor is there any specimen of *S. etheridgei* on this specimen.

*Ramose* *Streblotrypa*; apertures oval, rows of zooecia not separated by strong longitudinal ridges; about 11 to 13 small mesopore pits in area beneath each aperture, with one additional large pit placed immediately above each aperture; central bundle of small tubes developed; zooecial tubes with both inferior and superior hemisepta.

The zoarium is ramose; the holotype has a normal width of about 2 mm., but is wider before division of the branch occurs. The zooecial apertures are oval, about 0.18 to 0.22 mm. long and 0.11 to 0.15 mm. wide, and are surrounded by very slight peristomes. The apertures are arranged in about 30 longitudinal rows, and in steeply pitched diagonal rows. In each row the apertures are rather widely spaced, the distance between their centres being about 0.45 to 0.7 mm., the spacing becoming rather closer just before bifurcation than it is on the rest of the branch. In the holotype there are about 16.5 apertures in each row in 10 mm. The rows of apertures are not separated from each other by strong longitudinal ridges; the areas of mesopore pits beneath the apertures each contain about eleven to thirteen small pits, with one additional much larger pit placed immediately above each aperture; this large pit is usually oval, with its longer diameter at right angles to that of the aperture, or is slightly crescentic in outline, and it may be up to 0.11 × 0.6 mm. in diameter; the small mesopore pits are usually about 0.3 mm. in diameter, and are arranged in a fairly constant pattern, with two lateral, slightly curved rows, each of about five pits, separated by a median ridge, which bifurcates below the aperture, and in the small triangular space thus formed there are from one to four more pits.

Internally, the central part of the zoarium is occupied by a bundle of smaller vertical tubes about 0.65 mm. in diameter; the zooecia on each side are placed at an angle of about 25° to 30° to these tubes, and when they reach the cortical zone they bend sharply to meet the surface at right angles. No diaphragms are developed, but both superior and inferior hemisepta occur, both placed well within the tubes, the inferior hemisepta being rather closer to the surface than the superior.

Well-preserved specimens of this species are clearly differentiated from the much more common *S. marmionensis* by their surface characters, and particularly by the presence of one much enlarged mesopore pit above each aperture, and by their larger size; on weathered surfaces, the difference in the surface appearance between these species is not always so distinct—on one surface of the holotype which had been exposed by weathering and which Bretnall described, the walls between the large pits and the apertures had been broken down so that the apertures appeared long and oval and the tubes seem to meet the surface obliquely, and on this surface the appearance is not very different to that of weathered specimens of *S. marmionensis*; in other specimens the large pit has been made more prominent by weathering where its infilling has been more resistant to weathering than the surrounding walls.

Bretnall's Pl. i, fig. 7, is apparently taken from a specimen of *S. marmionensis*, and could not possibly be a figure of the holotype of *S. etheridgei*.

There is no described species of *Streblotrypa* with which this species could be closely compared.

#### Genus RHOMBOCLADIA Rogers, 1900.

*Rhombocladia* Rogers, 1900, 11; *Rhombocladia* Rogers, Moore, 1929b, 148.

*Genotype*: *Rhombocladia delicata* Rogers, 1900.

*Range*: Pennsylvanian to Permian.

*Zoaria* consisting of compressed, dichotomously dividing or irregularly reticulating stems, poriferous on one surface; acanthopores, sometimes of two sizes, abundant between the apertures on the obverse surface; reverse surface covered by a thin lamina ornamented by growth lines. Zooecia tubular, as in *Rhabdomeson*, arising from the

*reverse surface and approaching the obverse surface obliquely; vestibules shallow, vertically walled; hemisepta present, diaphragms present or absent.*

Moore (1929*b*) has very clearly re-described the genotype of *Rhombocladia*, which is "not uncommon in Pennsylvanian strata at widely different stratigraphic horizons in Texas, Oklahoma, and Kansas" and in Missouri; *R. delicata* has also been recorded and figured (Johnsen, 1906, 158, Pl. xi, figs. 30*a*, *b*) from the Fusulina Limestone of the Carnic Alps. Nikiforova (1934, 394) has recorded but not described a second species, *R. donaiica*, from the Upper Carboniferous of the Djulfa Basin in Russia. It is therefore very interesting to find two distinct species of this rare genus in the Permian of Western Australia, one a fairly abundant form in the Callytharra and the other a rare form in the Nooncanbah Series.

RHOMBOCLADIA MINOR, n. sp. Pl. v, fig. 5; Text-fig. 45, 46.

*Horizon and locality:* Callytharra Series, below Callytharra (holotype) and west of Callytharra (F 798, Commonw. Palaeont. Colln.), Wooramel R.

*Holotype:* F 805, Commonw. Palaeont. Colln.

*Very fine Rhombocladia, zoecia usually in three rows, acanthopores numerous and very fine; reverse surface flattened.*

The zoarium is irregularly reticulate, consisting of narrow, compressed branches, 0.46 to 0.57 mm. wide, and poriferous on one surface only; the branches bifurcate at intervals of about 1.5 to 2 mm., and in some fragments adjacent branches unite after bifurcation, so that some reticulation of the branches of the colony apparently occurred. The obverse surface is strongly convex and bears three, very rarely two, rows of zoecial apertures; the interspaces between the apertures are rounded and are ornamented by very numerous, tiny acanthopores, usually in two rows where the interspaces between the apertures are narrow and closely scattered on the broader interspaces; no large acanthopores occur. The apertures are oval, 0.24 to 0.29 mm. long and 0.1 to 0.15 mm. wide, and the centres of successive apertures in the same row are spaced 0.49 to 0.84 mm. apart, with about 16 in 10 mm. The vestibules are very shallow, but their walls are vertical. The reverse surface is flat and is covered by a very thin, semi-transparent lamina, ornamented by forwardly-directed U-shaped growth lines. The outlines of the recumbent parts of the cells are clearly shown through this lamina, and their shape is the same as that described by Moore in his revision of *R. delicata*. No diaphragms could be seen, and the hemisepta, if present, would not be visible in the part of the cells shown. This lamina projects to form a narrow flange around the obverse surface. Unfortunately the specimens are so fragmentary and so fragile that making thin sections proved impracticable.

This species is represented by abundant small fragments in material from the Callytharra. It is a much smaller species than *R. delicata*.

RHOMBOCLADIA SPINULIFERA, n. sp. Text-fig. 48.

*Horizon and locality:* Nooncanbah Series, Keevie's Well, 8 miles north of Mt. Anderson Homestead.

*Holotype:* 20944*b*, Univ. W. Aust. Colln.

*Rhombocladia with zoecia in four to six rows, acanthopores numerous, small, in a single row on the interspaces.*

The zoarium is irregularly reticulate, composed of compressed branches 0.7 to 0.95 mm. wide, poriferous on one surface only. The branches bifurcate rapidly, at times within 3 mm., and there was apparently also some irregular reticulation of the colony. The obverse surface is convex, and there are usually from four to six rows of zoecial apertures, but the number of rows and the arrangement of the apertures in them is somewhat irregular because of the rapid bifurcation of the branches. The interspaces between the apertures form ridges which bear a single row of small acanthopores, about 20 around each aperture; no large acanthopores occur. The apertures themselves are oval but the ridges around them are, in places, hexagonal in shape; the vestibules slope steeply inwards from the interspaces, except at the posterior end of the apertures, where there is at times a flattened area behind the aperture; the apertures are 0.19 to 0.24 mm.

long by 0.16 mm. wide, and the distance between the centres of successive apertures where they are regularly arranged in rows is 0.47 to 0.56 mm. The reverse surface is flat, and is covered by a thin lamina on which there are very faint U-shaped growth lines; this lamina may project and form a narrow flange around the edges of the obverse surface.

Genus STREBLOCLADIA, n. gen.

*Genotype: Streblocladia excavata*, n. sp.

*Range:* Upper Pennsylvanian to Permian.

*Zoarium consisting of compressed dichotomously dividing or irregularly reticulate branches; branches celluliferous on one surface only; apertures elliptical, spaces between them at the surface occupied by numerous shallow pits of irregular shape; acanthopores absent; thin basal lamina with fine growth lines on reverse surface; internal structure as in Rhombocladia.*

This genus differs from *Rhombocladia* in much the same way as *Streblotrypa* differs from *Rhombopora*, except that the inter-apertural pits on the obverse surface are much shallower and much less regularly arranged than in *Streblotrypa*.

Numerous fragmentary specimens of *S. excavata* were associated with *Rhombocladia minor* in material from the Callytharra; *Septopora ? elliptica* Warthin, 1930, from the Wewoka and Holdenville Formations (Upper Pennsylvanian) of Oklahoma, is congeneric with this species; the zoarium of *S. elliptica* is described as "irregularly reticulate", and the same type of zoarium is developed in some specimens of *Rhombocladia minor* from Western Australia described here.

STREBLOCLADIA EXCAVATA, n. sp. Pl. v, fig. 7; Text-figs. 42, 43.

*Horizon and locality:* Callytharra Series, below Callytharra (holotype), and west of Callytharra (F 799, Commonw. Palaeont. Colln.), Wooramel R.

*Holotype:* F 806, Commonw. Palaeont. Colln.

*Fine Streblocladia, zooecia in two to three rows, surface between the apertures divided into shallow pits; reverse surface convex, obverse surface flattened.*

The zoarium consists of narrow, compressed, dichotomously dividing branches, 0.4 to 0.6 mm. wide, with successive bifurcations spaced about 1.5 to 2.5 mm. apart. The branches are celluliferous on one surface only. The obverse surface is flattened, and there are three, less often two, more or less regularly arranged rows of zooecial apertures separated by broad, flattened, slightly depressed interspaces. The zooecial apertures are oval, about 0.32 mm. long and 0.14 mm. wide, and their centres are spaced 0.6 to 0.98 mm. apart, with about 13.5 apertures in each row in 10 mm. The apertures are surrounded by slightly raised, narrow, distinct peristomes; the vertically walled vestibules are very shallow, and within them the cells bend sharply backwards towards the basal lamina. The surface between the apertures is divided into shallow, irregularly shaped pits; there is frequently one larger and deeper pit of fairly regular shape (broad close to the aperture and narrowing gradually backwards) placed at the proximal end of the aperture. No acanthopores occur. The reverse surface is broadly convex, and is covered by a thin basal lamina, which forms also a thin, upwardly directed flange along the edges of the obverse surface; the reverse surface is ornamented by fine forwardly directed U-shaped growth lines, parallel to the growing end of the branch. The basal lamina is very thin and is semi-transparent, so that, as in *Rhombocladia minor*, the outlines of the cells can be plainly seen through it.

*Index to Genera and Species.*

The horizon from which each species is recorded in this paper is indicated as follows:

C., Callytharra Series; B., Barrabiddy Shale Series; Cun., Cundlego Series; W., Wandagee Series; N., Nooncanbah Series.

An asterisk indicates that previous records of the species have been from outside Western Australia, or from a different horizon in Western Australia.



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## EXPLANATION OF PLATES IV-V.

## Plate iv.

Fig. 1.—*Fistulipora crescens*, n. sp. Lateral view of a toptype (22123b, Univ. W. Aust. Colln.),  $\times 1$ .

Fig. 2.—*Hexagonella densa*, n. sp.—Holotype,  $\times 1$ .

Fig. 3.—*Hexagonella australe* (Bretnall). Holotype,  $\times 1$ .

Fig. 4.—*Hexagonella lineata*, n. sp. Surface of a toptype (F 17569, Aust. Mus. Colln.),  $\times 1$ .

Fig. 5.—*Fenestrellina chapmani*, n. sp. Obverse surface of a toptype (F 789, Commonw. Palaeont. Colln.),  $\times 10$ .

- Fig. 6.—"*Sulcoretepora*" *meridianus* (Etheridge). Surface of the holotype,  $\times 10$ .  
 Fig. 7.—*Minilya amplia*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 8.—*Fenestrellina alia*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 9.—*Fenestrellina sparsigemmata*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 10.—*Fenestrellina affluensa* (Bretnall). Obverse surface of a specimen (F 782, Commonw. Palaeont. Colln.) from the Callytharra Series, west of Callytharra,  $\times 10$ .  
 Fig. 11.—*Septopora ornata*, n. sp. Obverse surface of the holotype,  $\times 10$ .

## Plate v.

- Figs. 1-2.—*Synocladia spinosa*, n. sp. 1. Natural mould of the obverse surface of a toptype (22134b, Univ. W. Aust. Colln.),  $\times 10$ . 2. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 3.—*Septopora ornata*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 4.—*Penniretepora triporosa*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 5.—*Rhombocladia minor*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 6.—*Penniretepora fossata*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 7.—*Streblocladia excavata*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Fig. 8.—*Goniocladia timorensis* (Bassler). A specimen from the Nooncanbah Series, 9 miles E.N.E. from Trig. Stn. G2, St. George's Ra. (2757e, Univ. W. Aust. Colln.), showing the base and part of the reverse surface of the colony,  $\times 1$ .  
 Fig. 9.—*Penniretepora granulata*, n. sp. Obverse surface of the holotype,  $\times 10$ .  
 Figs. 10-11.—*Streblotrypa marmionensis* Etheridge. 10. Surface of a toptype (F17551, Aust. Mus. Colln.), showing the appearance of the surface in very well preserved specimens,  $\times 10$ . 11. Surface of the holotype, which is a rather weathered specimen, in which the longitudinal ridges between the rows of zooecia do not form such a prominent feature on the surface,  $\times 10$ .  
 Fig. 12.—*Streblotrypa etheridgei* Bretnall. Surface of the holotype,  $\times 10$ .  
 Fig. 13.—*Rhombopora multigranulata* Bretnall. Surface of the holotype,  $\times 10$ .  
 Fig. 14.—*Rhabdomeson mammillata* (Bretnall). Surface of the holotype,  $\times 10$ .

## ALEXANDER GREENLAW HAMILTON.

1852-1941.

*(Memorial Series, No. 10.)**(With Portrait.)*

The membership, past and present, of the Linnean Society of New South Wales includes many distinguished names in the scientific world, names such as T. W. E. David, J. J. Fletcher, W. A. Haswell, C. Hedley, J. P. Hill, A. H. S. Lucas, Wm. Macleay, C. Martin, Elliot Smith, J. T. Wilson, with R. H. Cambage, H. J. Carter, R. Etheridge and J. H. Maiden; names of men whose services to science—either as research students or as promoters of scientific work—have earned for the society, even during the relatively short time it has been in existence, an honourable place in the world of science. These all, and others still among us, have striven, or are striving, whole-heartedly, to maintain the high standard set by the pioneers of scientific research in Australia. But no member of the Linnean Society has merited more the admiration, respect and affection of his colleagues than the late Alexander Greenlaw Hamilton—admiration and respect, not only by reason of his unwavering devotion to family, official, civic and scientific duties, but also because of the marked success won by him in the teeth, as it were, of armed antagonisms opposing his ascent right up the ladder of fame from the lowest rung; affection, because of his unfailingly friendly, cheery, encouraging, exhilarating and inspiring nature.

His career is a notable example of the prodigious amount of work of solid worth which self-help may accomplish, for Hamilton's success lay, mainly, in his instinctive and intimate communion with Nature; his unaided but well-developed powers of observation and reflection; the tireless energy and buoyancy which were natural to him, together with his inherent regard for Truth. His quest was Truth first and Truth last. Scientific fame and social recognition counted but little with Hamilton compared with his loyalty to Nature herself who, it would seem, had cast her spell upon the youth as she had done to naturalists before him, such as Louis Agassiz, Mendel, John Muir, and Darwin.

To speak of his love—his "queerness" as some of the rustics dubbed it—for Nature, was but to epitomize his love for "man and bird and beast"; it was, in short, to summarize his life's ambition.

Hamilton does not appear to have sought either popularity or the affection of his fellows. He certainly was decidedly popular and he was affectionately regarded by all, but that was simply the natural result of his inherently tolerant and affectionate nature. He had "cast his bread upon the waters and it had returned to him after many days". "He liveth well who loveth well both man and bird and beast."

Absorbed in his scientific work, and in service to his fellows, he sought to inspire them with a love for Nature, and with the desire and will to co-operate with each other in all matters tending to the common good. As E. E. Pescott, a Victorian colleague, testifies: "It was his power of inspiration that was a real force. 'Have you ever published anything?', he would say, after a joint excursion with a colleague who had not yet published. Then he would urge the case for publication so eloquently as to persuade his colleague to commence taking careful observations with the idea of publishing. He was a great yet humble man, and I shall always feel better for having known him. . . . 'Work, work, and tell the world about it, so that you may help someone else' was his motto, and he was unselfishness itself in all his advice."

When others plagiarized his work, or were given, as sometimes happened, credit for observations or addresses given by himself, he would reply "Nobody knows which is which, and it will be all forgotten in a month". (Pescott.)

Whatever success he obtained during his lifetime was due, not so much to elaborate and rhetorical presentations of his work and its worth, as to the patient and tireless search for facts rather than for sensational novelties. In short, he adopted the methods employed by great yet modest naturalists before him, men like Darwin, Farrer, G. K. Gilbert, Haswell, W. H. Hudson, Mendel, John Muir, A. R. Wallace and Waterton. There were only twenty-four hours in the day for Hamilton, and he, like the great ones mentioned above, chose God before Mammon.

Another significant feature in his personality lay in the fact that, in addition to his acknowledged skill in various biological matters, he was—as W. J. Enright and E. E. Pescott state—equally at home with school children, with more advanced students, with research scientists, with farmers, drovers, lumbermen, with the man “on the land”, and with the man “on the street”.

The general testimony of his various colleagues is that he was a born naturalist—the Admirable Crichton in all things pertaining to Nature as she is revealed in the Australian “bush” and along the shoreline—an ideal parent and home companion; an eminently successful teacher (reminiscent of Pestalozzi, according to T. T. Roberts, a colleague); an esteemed citizen; a skilled craftsman; an artist and musician of no mean ability; a true sportsman; and a gentleman.

Among the successes which he gained, despite his innate modesty, may be mentioned the highly satisfactory result of his appeal for the active recognition of the value of Natural History studies in Primary School curricula. This appeal was made at the Educational Conference of April, 1904, and it induced the Department of Education—on the motion of Sir George Knibbs—to include the study of Nature (with elementary physics, chemistry, zoology, botany, geology and mineralogy) in the Primary Schools of the State.

F. T. Berman, a colleague and friend of more than thirty years' standing, quotes his personal experience during which “A generation has passed since Hamilton conducted his memorable pioneering work. Teachers and pupils of more than three decades have built upon the foundation laid by him and reared a superstructure which has been productive of a better understanding and appreciation of that which is written ‘in the manuscripts of God’”.

W. J. Enright, well known to Linnean members as the stalwart champion of the cause both of Nature Study, and of Nature herself, in the Hunter and Manning districts, pays a high tribute to the work and character of Hamilton: “With all his wide knowledge he combined the ability to adopt his addresses to the minds of the various audiences which he addressed. His never-failing humour helped to capture and maintain the interest of his audience. . . . His knowledge of Australian bird life was very great . . .” extending to a close knowledge of “the songs and notes of the birds, together with their habits”.

Enright considers that Hamilton, like Joseph Leidy, would never become tired of life so long as there existed, alongside of him, and easily accessible, even so humble an organism, or organic trace, as an intestinal worm, a fragment of fossil bone, a grub, or a diatom, new to science.

P. R. Cole, a colleague of long standing, furnishes an appreciation of Hamilton in which he stresses “His gentleness, constancy, magnanimity, his originality in research, and his genial friendship, which all combined to exert a subtle and powerful influence upon both students and all who knew him”.

The written, or spoken, appreciations of other educational colleagues—including P. Board, F. Bridges, Margaret Deer, Thistle Y. Harris, T. T. Roberts and S. T. Turner—are all confirmatory of the eulogies of Berman, Cole, Enright and Pescott. S. T. Turner tells how “His approach to science as a teacher was not that of a dry-as-dust Professor with . . . hair-splitting definitions . . . but of one interested in life activities. . . . He was an accomplished artist who could sketch rapidly the various illustrations required in his lectures and publications. . . . He was incapable of an unkindly thought. . . . All teachers who came under his influence were impressed by his gentle, kindly, co-operative nature. He was an inspiration to Nature students.”

This brief appreciative note dealing with Hamilton, the man, will serve as an introduction to the accompanying condensed account of his life activities as a citizen, a teacher, and as a scientific research student.

At the outset, I desire to record the deep debt of gratitude which I owe to various colleagues and friends of Hamilton, without whose help the wealth of material from which this note has been prepared, would have become available only with the greatest difficulty.

Hope had been placed, at the beginning, upon obtaining access to an autobiography which Hamilton is known to have prepared. Failure to trace this valuable document led to inquiries for the needed information concerning Hamilton's activities from various scientific colleagues. But Hamilton had outlived all his old-time colleagues in science, from whom valuable reminiscences might be expected to have been obtained. Ample material, however, was forthcoming finally through the zealous and friendly efforts of F. T. Berman, formerly Head Master of Fivedock Public School, and E. A. Hamilton, veterinary surgeon and a son of A. G. Hamilton. F. T. Berman was associated intimately with A. G. Hamilton in the Department of Public Instruction for a period exceeding thirty years. To Berman also we are indebted for obtaining written tributes of marked esteem and affection from Hamilton's colleagues at the Training College and elsewhere, namely, P. R. Cole, Miss M. Deer, T. T. Roberts, Miss Thistle Y. Harris and S. T. Turner. To E. A. Hamilton we are indebted for the notes on the general family, official, and civic activities of his father, and for the letters of appreciation from W. J. Enright and E. E. Pescott.

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Alexander Greenlaw Hamilton was born at Baillieborough, Ireland, on 14th April, 1852. His father was Alexander Greenlaw Hamilton, whose father, John Hamilton, had married Sarah Greenlaw, of Greenlaw, Scotland. John Hamilton had seen active military service in the Peninsular War; in the war with the United States in 1812; and at the Battle of Waterloo, where he was awarded the Waterloo Medal for valour. Our Hamilton's mother was a daughter of William Wynne of Killybegg, County Louth, near Ardee, Ireland.

Hamilton arrived in Australia, with his father and mother, in or about his fourteenth year. In 1866, he succeeded in passing the examination test demanded by the Education Department of New South Wales for candidates desirous of teaching in "country schools". Although successful in the written and oral tests, he was considered to be too young to be placed in full charge of a school, and a compromise was effected whereby he, although only fourteen years of age, gave the whole of the instruction, whereas, officially, his mother was recognized as the responsible agent to the Department.

This school was at Fish River Creek. Somewhat later, the family moved to Meadow Flat, where Hamilton was placed officially in charge of the school. In 1870, he was appointed to the position of assistant at St. Mary's Church of England School at South Creek. At a later stage, but during the same year, he attended a course of training for teachers given at Fort Street, Sydney, and, in October of that year, he was promoted to the charge of the public school at Guntawang, a position which he held until 1887.

Here, at Guntawang, commenced a remarkably happy period of his life. Here it was that he met and married Emma Thacker, of Guntawang. Hamilton was married on the twenty-first anniversary of his birthday, his wife being but eighteen years of age. She it was who became a lifelong companion and helper to him, accompanying him on various lengthy excursions for the collection of Natural History material. Here it was that he commenced his long and fruitful communion with Nature; here it was that his sons were reared and introduced to the secrets and beauties of Nature; and here it was that many lifelong friendships were established with leaders of scientific thought in Australia.

Here also it was that he created, gradually, a deep interest in Natural History objects among the country people in his neighbourhood, and the members of Hamilton's family have very lively recollections of the non-co-operative and vigorously protesting representatives of the local fauna which were from time to time unceremoniously introduced to

the attention of the Hamilton household—birds of all sorts, graceful marsupials, writhing snakes, bloated lizards, fearsome insects and other arthropods, many things slimy and slippery, together with uncommon plants. The collections consisted generally of organisms which were considered, by the youthful collectors, to possess some special feature of attractiveness, such as uncommon beauty or ugliness, particular aggressiveness or dangerousness.

In addition to these job lots arriving, in impromptu fashion, from all points of the compass, Hamilton himself had gathered around him his own particular pets, ranging from birds and lizards to kangaroos, wallabies and opossums. One of his greatest treasures was a platypus possessed of very retiring habits. It preferred darkness to light, but not "because his deeds were evil". It was made as comfortable as local conditions permitted under the peculiar circumstances, seeing that Hamilton's small home plot possessed neither a handy river nor lake in whose banks the strange guest might conceal itself. Finally, however, it was persuaded to be happy and comfortable in a nest improvised from a box attached to a tree stump. Under cover of night, the wary monotreme would take its courage "in both hands", as it were, and, making use of the darkness as a substitute for its natural gloomy underground passage made in the river or lake bank, would venture forth and collect worms and other gastronomic delicacies (which had been supplied with a generous hand by the Hamilton family) from a tub of water which the unsuspecting pet possibly mistook for an inlet of its own natural river or lake-like expanse of same.

Hamilton possessed a very strong community spirit which found expression in whole-hearted participation in the social activities of the various districts in which he happened to live. These activities he extended in certain directions. At Guntawang, for example, he was responsible for the establishment there of a School of Arts, the work of Librarian devolving upon himself. Indeed, the amount of scientific, social, and sporting activities which he compassed in non-official hours was a never-failing source of wonder to his family, for, although his chief hobby was Nature Study in its various ramifications, nevertheless, at Guntawang, at least, he was known not only as a naturalist, but as an enthusiastic cricketer, musician, sketcher, painter, photographer, and general helper and counsellor. In all the local musical activities, whether sacred or secular, he was *facile princeps*. He was the organist of the church and leader of the choir, as well as being the acknowledged leader of the local concerts and dramatic performances. In local cricket circles his assistance was valued specially in the batting and wicket-keeping departments. The gloves worn in the country at that period gave insufficient protection against the incoming tendency to fast overarm bowling—as opposed to the old underarm delivery—with the result that every finger of his right hand appears to have suffered severely, either by having a bone broken or a joint dislocated due to his own stubbornness in maintaining his close stand behind the wicket.

Sketching ("drawing") and painting were not hobbies so much as means to an end, namely, the simplification and clarification of Natural Study descriptions. He appeared to possess a special gift in drawing, whereby he caught the natural expression of the various subjects chosen for illustration. This gift he employed freely in his earlier studies in the preparation of coloured illustrations of plants, birds, and other objects of the district for identification by William Woolls, Baron von Mueller, and other authorities, but all strangers to the district. His black-board sketches, moreover, proved to be of most definite assistance to his Natural History classes.

Photography was especially welcome to him as being a most marked help in his studies. His first attempts were with the cumbersome and obsolete wet-plate system. This, as is well known, was a lengthy and difficult process, involving the employment of the focussing apparatus, the painting of the plate, the screening of same, the exposure, and the development at once afterwards. In the Guntawang days (1870–1887), many of the local residents had considered him to be a little "queer", because of the meticulous caution and care taken by him in observing the habits of animals, insects and plants; but when he went through the solemn ceremony of photography with his high tripod and its black cloth, the wet-plate, the focussing details, the seriousness observed by him in making the important plate exposure, the careful extraction of the plate and develop-

ment of same, then, indeed, the rustics felt confident that their school teacher was not "quite like" other men in the settlement.

The photographic hobby remained with him to the end, and very numerous were the excellently coloured lantern slides of plants prepared by him.

Despite all his other activities, he was an omnivorous reader. He spent all that he could afford (and even what he could not really afford, according to family testimony) on books. Hamilton possessed one point, at least, in common with his platypus, in that he pursued his hobby of reading much about the same time that the beloved platypus was pursuing its own hobby of exploration and grub-hunting in the mud of the big tub, namely, night time, when "man's work is done", and field work, therefore, was supposed to be impracticable even for Hamilton. Many a time the sight of "Greenlaw" coming home quite unobtrusively, but with his bag suspiciously heavy, would cause his wife to wonder as to the nature of the contents of that same bag, for, if of books, it might have some slight effect on the domestic budgeting for the month.

After the Guntawang days, he became a golf enthusiast, and, on the steep slopes of the coastal area near his home or the school, he enclosed an area with high wire netting so as to safeguard the golf ball when practising "shots".

Hamilton was a keen collector, but, withal, he had a marked aversion to cruelty in any form. This would not allow him even to keep pets in confinement against their will. He inculcated in the children of his district the love of sympathetic observation of bird activities in the field, so as to obviate the wanton destruction of birds for idle curiosity. The studies of animal life in their natural surroundings involved the taking of lengthy excursions, but Hamilton was an accomplished and tireless walker. As a naturalist he was to New South Wales much the same as John Muir was to California, the lover and protector of Nature.

Settlement at Guntawang was markedly scattered, and medical aid, from accredited practitioners, was almost non-existent. Hamilton naturally stepped into the breach in emergency, and was called upon for help in cases of accident, snake-bite, and other ailments, requiring skill beyond that possessed by the ordinary bushman.

In 1887, he accepted the position of Head Master of the Mt. Kembla Public School, and was introduced thus to an entirely new environment. From the open forests of the inland area he now came to the rain forest of Illawarra; from the dry land of the inland slopes he came to the seaside with its shoreline and its teeming wealth of life. The neighbours here were not "settlers", but coal miners in the main. The rain forest which clothed the neighbouring ranges gave him contact with a fauna and flora possessing appearances and habits differing markedly from those of the more open country of Guntawang. In his new setting he had the glorious sandy beaches and the shoreline life of Illawarra, the rolling country of the coast, with its rich volcanic soil, the abrupt escarpments and profound gorges to the immediate west, and the swampy "tops" in the sandstone country which were co-extensive with the high plateaus to the west.

The proximity to Sydney also enabled him to establish closer contact with many friends made during the joint study of various branches of science. Into the social activities of the great coal-mining district he entered also enthusiastically, establishing night classes for the study of subjects (such as geology) likely to be of use to men engaged in a mining career. The disastrous explosion at the Mt. Kembla Mine, with its heavy toll of serious accident and life, found him among the first at the pit's mouth offering his services in any helpful capacity.

It was about the year 1905 that he was promoted to the charge of the Public School of Willoughby. It would appear that his masterly knowledge of Nature Studies had been brought forcibly under the notice of the Department of Education in 1904 by reason of his clear and convincing presentation of their value at an important Educational Conference, and, as a result, he was now appointed Lecturer in Natural History and Botany at Blackfriars and Hurlstone Training Institutions, in addition to his responsibilities as Head Master at Willoughby. These arduous duties he conducted conscientiously for two years, at the expiration of which time (1907) he was appointed Lecturer in Biology and Nature Study at the Teachers' Training College, Sydney University.

The dual responsibility of administering a large public school and delivering lectures in other centres had been a heavy tax on his health, and the appointment to the Training College came, therefore, as a happy release from the former unsatisfactory official position.

His term of office at the Training College proved to be another remarkably happy period of his life, inasmuch as his main hobby had now become his full-time occupation. A marked improvement in his general health soon became noticeable.

This appointment also enabled him to enter more closely into the activities of the Linnean Society, which had always exerted a peculiar attraction for him. He was one of the early members of the Society, having joined in 1885. He was a member of the Linnean Council for many years, and occupied the Presidential Chair during the period 1915–1917. He appears to have been the last of the members of the Society who had a personal acquaintance with Sir William Macleay.

He took a very active and helpful interest in various other scientific and Natural History societies. He was a member of the Royal Society of New South Wales; the Royal Zoological Society of New South Wales; the Naturalists' Society of New South Wales (occupying the Presidential Chair over a considerable period); the Wild Life Preservation Society of Australia; the Wattle League; the Microscopical Society of New South Wales; the Gould League of Bird Lovers.

Hamilton's family included four children, three sons—Charles Greenlaw, Harold Wynne and Edgar Alexander—and one daughter—Jocelyn Emma. The sons were born at Guntawang, the daughter at Mt. Kembla. Charles, the eldest, resides in Western Australia. He has always been known as a keen naturalist and a prime mover in the development of Natural History studies in that State. In the portrayal of animal and plant life with pencil and brush he has inherited the recognized skill of his father. Harold, deceased, was a Lecturer at the Teachers' Training College, Sydney University. He will be remembered as having possessed the same helpful, cheerful, friendly, and affectionate nature, with the same love of Nature, as his father. Edgar, the youngest son, a veterinary surgeon, is a retired Government official. He maintains the old home at Chatswood, with the fine orchid collection, both of endemics and exotics (and which he has even extended), built up years ago by his father.

Hamilton passed away on the 21st October, 1941, at the advanced age of eighty-nine years and six months. His end was remarkably peaceful, the only marked inconveniences suffered by him, in his last years, being those arising from failing eyesight.

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*Scientific Activities.*—Hamilton's contributions to science cover a wide field of biology, including careful observations on the fertilization of plants belonging to various families (Orchidaceae, Verbenaceae, Eupomatiaceae, Proteaceae, Goodeniaceae, Candolleaceae, etc.); on xerophily in Australian plants; on the carnivorous activities of the Droseraceae and other Australian plants; on Domatia and other peculiar features, in certain endemic and exotic plants.

These Nature Studies were commenced at an early age. At Guntawang his attention was attracted first to the local orchids which he commenced to represent by means of sketches with washes of colour. From these sketches the species were readily recognizable by W. Woolls and R. D. Fitzgerald. He made considerable collections of orchids for Fitzgerald. Thence he passed on to the more detailed study of the methods of fertilization observed by many species of orchids. In addition he published a list of the Mudgee district orchids in these PROCEEDINGS, and in these notes he made special references to the methods of pollination observed in various species. In later papers he dealt with the methods of fertilization observed in plants belonging to families other than the orchids.

The more important results of Hamilton's researches were published in these PROCEEDINGS, his first contribution appearing in 1885 and the last in 1927. He also read papers at a number of Australasian Association for the Advancement of Science meetings and wrote numerous popular articles on Natural History subjects which appeared in the *Public Instruction Gazette* and the *Sydney Quarterly Magazine*. In 1937, a number of

his articles which had appeared earlier in the *Sydney Quarterly Magazine* were published in book form under the title "Bush Rambles".

His attention had been turned also to birds, the names of which were supplied to him, from his sketches, by the staff of the Australian Museum.

As a result of this careful work, he became a valued correspondent with many scientific workers in Australia, such as F. M. Bailey, R. H. Cambage, R. D. Fitzgerald, J. J. Fletcher, J. P. Hill, J. H. Maiden, Baron von Mueller, Baldwin Spencer and the Rev. Wm. Woolls.

Hamilton, in a public address, delivered in 1904, thus describes his early attempts at the study of Natural History:

"When I began my career in the service (Public Instruction), some thirty-four years ago, I was as ignorant of botanical knowledge as anyone could be. I had to teach myself botany. . . . I took long walks in the bush, and collected all the plants I could see. . . . I sat down afterwards with a folded sheet of foolscap and made pencil sketches (tinted with water colours) showing all the parts as well as I could. . . . The difficulty was to secure the names of the plants. . . . I became acquainted with Dr. Woolls, who promised to name the plants of which I sent the drawings. . . . Speaking once to a scientist in Sydney concerning a certain plant, he said, 'Why do you not write a paper on the subject?' My reply was, 'If I do, who would publish?'. 'Join the Linnean Society, and they will publish it'."

Thus it came to pass that Hamilton joined the Linnean Society, of which he was to become one of its most distinguished members and supporters.

From these beginnings with plants and birds Hamilton extended his studies to include the local fauna. Reference to this work is contained in his wide correspondence mentioned below.

Previously to 1904, Nature Study was not included in the Primary School curriculum, and Hamilton's official light, up to that date, had been practically hidden "under a bushel". But the Educational Renaissance Conference of April, 1904, afforded him the opportunity he sought for urging the claim of Natural History studies in Primary Schools.

Among other truths emphasized by Hamilton during, and after, the conference, may be mentioned:

"The scientific attitude of mind is the point to be aimed at. You must place your children in the position of independent observers, who are to form their own judgment of what they see. . . . What books would you recommend? First of all, the book of Nature. Books themselves, naturally, are useful. A teacher must have some knowledge of technical terms. . . . But for everything else, it must be a matter of observation. The systematic study of science . . . tends to lessen the destruction of natural objects of 'beauty'."

As one of his colleagues writes: "His scientific methods were not confined to detailed measurements and hair-splitting definitions, but were directed, more particularly, to the dynamic side, to the life activities of his favourite objects of study, namely, the animals and plants of the bush."

In the conduct of operations he emphasized "the necessity of making drawings with detailed notes of observations; of persistently comparing unlike objects. . . ." To him "it was a preparation for service. It was not time wasted. . . . It created an interest in one's environment; was conducive to accuracy, and lifted one above the dry details of everyday life."

At a very much later stage, Hamilton found himself unable to complete various papers in process of preparation on xerophily, owing to failing eyesight. It would appear that, prior to obtaining suitable apparatus for micro-photography, he had prepared very many careful drawings with the aid of the camera lucida. This work, to a very great extent, is held responsible for his optical trouble. The fact remains that the gradual development of "diffuse cataract" growth compelled him to halt in the midst of taking necessary observations in the preparation of notes intended for publication. Earlier examinations by specialists had suggested the probability of a successful operation being undertaken for cataract. Later, however, the prognosis was definitely unfavourable, suggesting that an operation might be attended by complete blindness,

owing to the existence of certain complications. Hamilton, thereupon, decided not to risk an operation. Certain undertakings of his thus remain uncompleted.

*Correspondence.*—An examination of his correspondence furnishes a clue to the almost incredible amount of assistance which he gave to workers in all branches of Natural History, branches also in which he himself was either an authority or an able collaborator. It reveals also the existence of many firm friendships made with scientists both in Australia and abroad. Some of the letters received by him are full of wit and caustic humour; some are of begging nature; most of them are informative; all are interesting.

One of the more notable and respected members of the pioneer galaxy whose work has raised the Linnean Society to first class rank in the world of science, one of the Linnean's real stalwarts, wrote humorously to Hamilton under date 19th September, 1892, congratulating him on winning the medal and prize (£25) awarded by the Royal Society of New South Wales for his excellent paper on the effect which settlement in Australia has produced on the indigenous vegetation. The letter illustrates the type of good-humoured badinage and chat with which the literary pioneers were accustomed to enliven and punctuate their periods of serious scientific work.

“. . . Well, you have received the medal, the ducats, and the marmalade . . . so be happy while you may. We shall be glad to put you up for the night of 5th October if you will promise not to wear your 'coronet' at dinner. Of course if you come to the meeting be prepared to mortgage the twenty-five pounds. . . . Possibly they will want to run you in for a donation to the building fund; these are some of the prospective penalties of greatness. However, if you come, I think I can promise to go with you if I may take a smelling-bottle; their meetings are so excessively 'royal' that one requires a pick-me-up of some sort; but, however limp I may be, you can rely on H—y being regally in evidence, not merely as our only representative in Australia of Modern Malacology, but as the representative and substitute for the British aristocracy, and in full bloom and glory at that; so bring your Windsor uniform and don't forget to sharpen your sword, so that if Lord Tumberumba or Viscount Wagga Wagga should get up and ask any awkward questions, such as whether you will kindly explain to the meeting why the native grasses refuse to grow on the telegraph poles or what you consider the most fattening diets (tin cans?) for a flock of billy-goats, you can not merely wither him with a glance, but afterwards fix him under the fifth rib with your weapon when you catch him alone in the passage. Note well, however, that no blood must be shed on, or in close 'contagion' to, the throne, only on the donjon without the keep, and near the prime mortar-board, so comply strictly with the etiquette of the royal precincts, or beware of being thrown to. . . . My wife says I seem to have lost my head; being a 'Rempublican', I suppose she means that I may be in danger of doing so if I am caught accompanying you to a meeting of Royalists. . . .

“However, one must have a little diversion, hence all this twaddle. . . .”

*H. A. Russell*, 1895, thanks him for the drawing of a meteor evidently found by A.G.H.

*C. Hedley*, 1893 onwards, requests Hamilton for snails like *Planorbis*. Congratulates him on his review of Ogilvie's "Mammals". In correspondence on botany he informs A.G.H. that "species mongers are no good to you" and proceeds to eulogize the philosophical botanical minds of Henry Deane, Manson Bailey and Ralph Tate. This leads to a discussion on the distribution of *Eucalyptus* in New Guinea and other extra-Australian localities.

*J. P. Hill*, 1895–1902. Hill advises publishers to attempt to persuade Hamilton to prepare volumes on mammals, birds, and botanical subjects. In passing he indulges in an encomium on the services of Manson Bailey to botany.

Hill was a close friend and an admirer of Hamilton's work, and he is credited with a statement to the effect that "he had never known anyone able to obtain such excellent results as Hamilton did with the scant equipment and means at his disposal; the ingenuity and resource shown by him in constructing his own equipment, being remark-

able, particularly in regard to his work with the microscope, with the preparation of sections, and so on."

*Wm. Woolls*, 1880-1892. Congratulates Hamilton, in many letters, on his skill and accuracy in preparing drawings of plants for identification; urges him continually to make collections of his district, and to correspond with Baron von Mueller, using his (Woolls) name for purposes of introduction. Commends his skill in securing valuable material in mosses, ferns, lichens, orchids, eucalypts, nardoo, etc. He extols the value of the drawings but points out the necessity of securing dried specimens in addition in the case of certain ferns and mosses, as even the best drawings fail to convey the full story. "Of some drawings I feel sure, as they are done so elegantly and bring out the particular features which I desired to see. In others . . . especially in some of the Epacrids and Composites . . . (24/12/80)." He also expresses the belief that the "Government should provide for you in one of our scientific institutions" (29/12/92)."

*Baldwin Spencer*, 19/5/98, and later, discusses the glands of the Phyllodineous Acacias, especially with regard to the reaction of ants to the phylloides. Spencer deplores the ravages of "bush fires in the Dandenong Ranges, whereby ferns, sassafras, cottonwoods, hazels, musk, etc., are all gone, and completely scorched up. . . . It will take years to restock and many local endemic forms may be lost to science".

He bemoans the fate of the Central Australian animals and plants as a result of the great drought of 1902. In 1899 he begs Hamilton to attend the A.A.A. Science Meeting for 1900, in Melbourne, and adds, as a special inducement, that J. J. Fletcher will be there.

*Baron von Mueller*, 1886-1887. With characteristically large and sprawling calligraphy von Mueller furnishes the names of various lichens, while in later notes, he discusses in detail the Lobelias of the Mudgee district, and, in conclusion, asks Hamilton whether he would like to join the Linnean Society of London.

*Alfred Russell Wallace*, 16/5/93. (It is a pleasure to read Wallace's letters, the writing is so clear, beautiful, and full of character.) In his note he wishes Hamilton to inform him "whether introduced plants *ever* replace native plants where the latter have *not* been interfered with by man" as bearing on the Darwinian view of "the greater power of northern plants over southern".

*Charles Badham*. Sends congratulations to Hamilton on his election as President of the Linnean Society of New South Wales. Thanks Hamilton for botanical assistance.

*J. H. Campbell*, a former Treasurer of our Linnean Society, writes (10/1/28), informing Hamilton of his great pleasure at being able to obtain the latest news of Linnean members and doings from his Australian friends Walkom, Andrews, and Dixon, who have just "called in at Ottawa on their way through".

*R. Broom*, 26/12/95, criticises the volume published by the Linnean Society of New South Wales dealing with Presidents and Fellows. "In preparing your Jubilee Record it is a pity you dealt only with the officials and your Macleay Fellows, for you leave out by far the greatest man that has been associated with the Society, namely, Elliot Smith." (Grafton Elliot Smith was a member for years.)

The correspondence includes letters also from *Marie Stopes* (seeking Hamilton's assistance in connection with a proposed study of proteaceous woods); *Lyon Phelps* of Yale University (proposing publication of notes by Hamilton on Australian writers in *Scribner's*); *L. Cockayne* (Notes on problems of Western Australian botany); *E. A. Newell Arber* (Furnishing detailed description of fossil Permian coniferous woods from the Mt. Kembla district); *F. Manson Bailey* (On determinations of Algae); *A. C. Haddon* (5/10/89) (Proposes collaboration with Hamilton on Actinia, etc.); *E. E. Pescott* (orchids); *E. P. Ramsay* (fishes); *H. M. R. Rupp* (lengthy correspondence on orchids); *R. T. Baker*, *E. Betche*, *H. J. Carter*, *W. P. Cullen*, *J. Milne Curran*, *Dr. Cox*, *W. J. Enright*, *A. A. Hamilton*, *E. Haviland*, *J. H. Maiden*, *J. G. Luehmann*, *A. J. North*, *C. T. White*, and many others, on subjects connected with the Australian fauna and flora.

## ARACHNID NOTES.

By FRANK H. TAYLOR, F.R.E.S., F.Z.S., School of Public Health and Tropical Medicine, University of Sydney.

(Nine Text-figures.)

[Read 30th August, 1944.]

ARGAS LAGENOPLASTIS Froggatt, 1906.

PROC. LINN. SOC. N.S.W., xxxi, 408.

Female.—Oval, widest slightly posterior of the anal opening (Figs. 1, 2). Margin (Fig. 3) about the same width as in *A. persicus* (Oken) composed of somewhat oblong units or 'cells' without a circular pit. Discs mainly round, arranged as shown in figure. Venter: anal opening (Fig. 4) somewhat posterior of the centre, anal ring smooth. Spiracles (Fig. 5) small, crescentic, cribriform, equal to half the diameter of the anal ring, its anterior margin slightly above the posterior margin of the third coxa; genital opening opposite coxa II. Capitulum (Fig. 6): base ventrally with two long stout, post-hypostomal forwardly-directed hairs. Palps (Fig. 7) only slightly longer than hypostome, second segment the longest, third segment the shortest, first and fourth segments about equal in length. Chelicerae and hypostome as illustrated (Fig. 8a, b). Legs: coxa I is widely separated from coxa II, coxae II-IV about evenly separated, tarsus of leg I (Fig. 9) as illustrated. Colour: dorsum dark reddish-brown, dorsal border somewhat

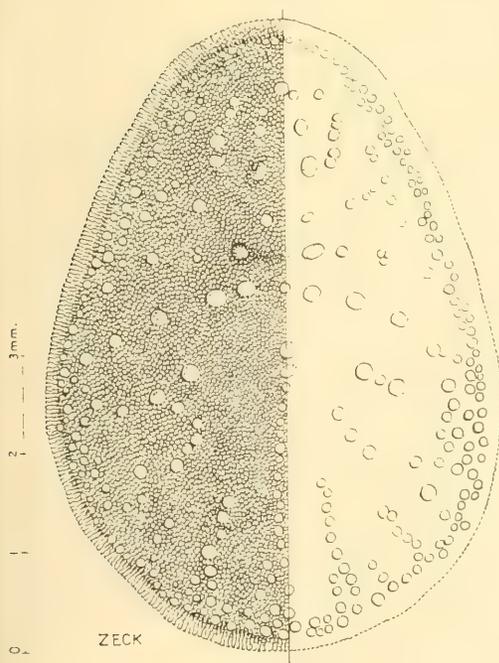


Fig. 1.—*Argas lagenoplastis* Froggatt.  
♀, dorsal view.

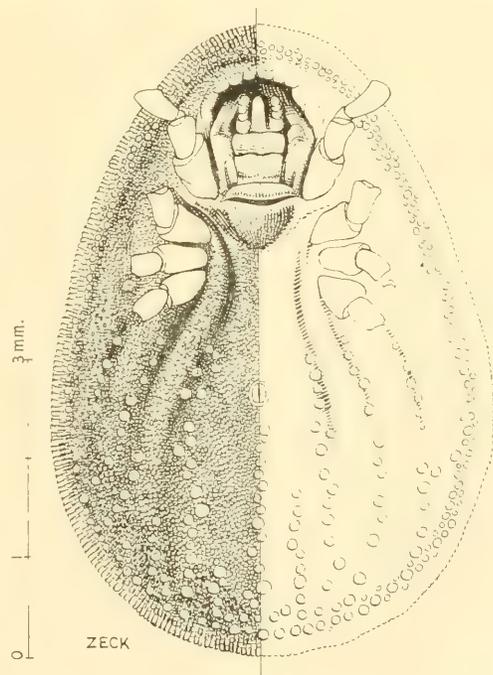


Fig. 2.—*Argas lagenoplastis* Froggatt.  
♀, ventral view.

paler, legs light reddish-brown, bases of trochanters appear to be very pale, anal opening dull whitish, almost ashen. Length:  $6.0 \times 4.5$  (*vis*) mm.

*Host*: *Hylochelidon ariel* Gould (Fairy Martin).

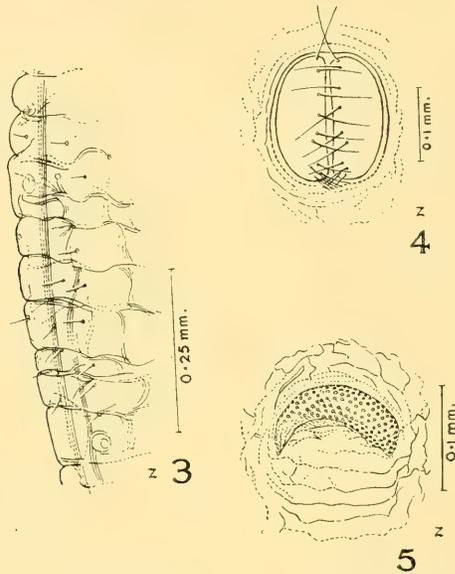
*Loc.*: N.S.W.: Gilgandra.

Froggatt's description is inadequate and without illustrations. It reads as follows:

"Length  $2\frac{1}{4}$  lines. Reddish-brown, with the dorsal surface mottled with light yellow; undersurface dull yellow, with the legs very pale yellow to almost white. Broadly oval, flattened on the dorsal surface, with the integument finely rugose and marked with irregular depressions.

"*Hab.*—Merriwa and Narromine, N.S.W.

"This tick is common in the clay nests of the Fairy Martin or 'Bottle-nest Swallow', *Petrochelidon (Lagenoplastes) ariel*. . ."



Figs. 3-5.—*Argas lagenoplastis* Froggatt. ♀. 3. Portion of integument from posterior dorsal border. 4. Anus. 5. Ventral view of left spiracle.

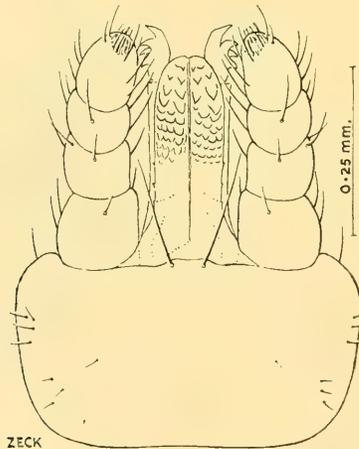
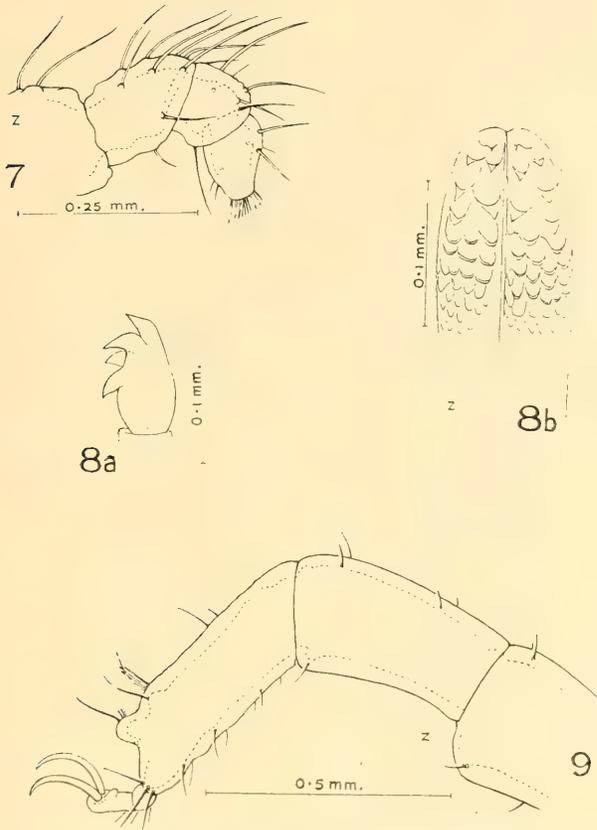


Fig. 6.—*Argas lagenoplastis* Froggatt. ♀. Capitulum.



Figs. 7-9.—*Argas lagenoplastis* Froggatt. ♀. 7. Right palp. 8a. Digit. 8b. Hypostome. 9. Leg I.

Froggatt also stated that Mr. Masters had shown him specimens in the Macleay Museum that he (Masters) had collected in Queensland about 1874.

Froggatt's type and other specimens are lost. They are not in the Entomological Collection in the Department of Agriculture, Sydney, neither are they in the Froggatt Collection at the Council for Scientific and Industrial Research, Division of Entomology, Canberra.

It is presumed therefore that the species under review from Gilgandra is the same as that which Froggatt named.

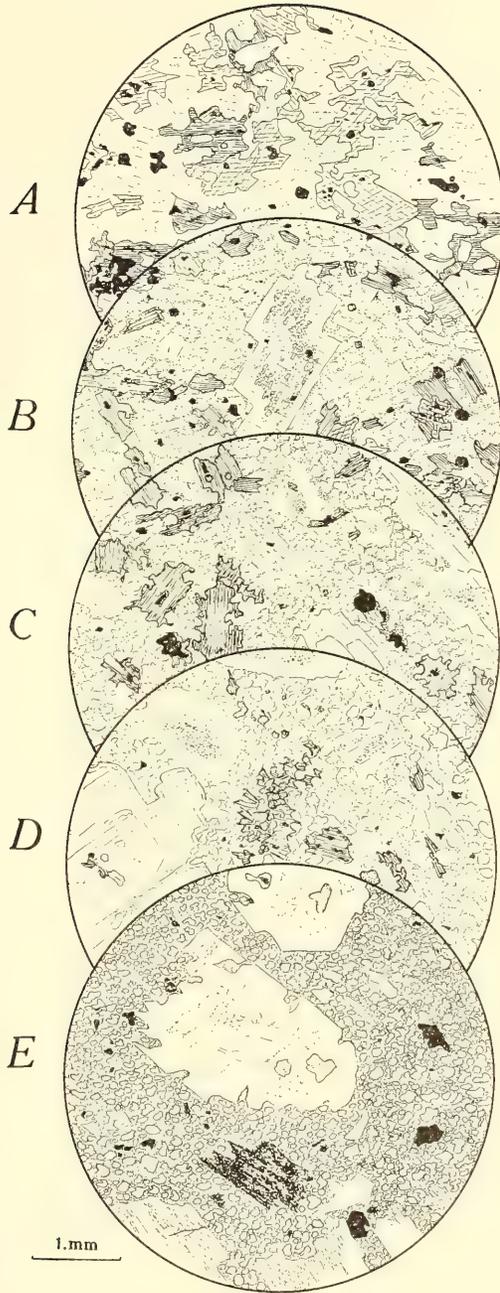
The description which I have given should be sufficient, with the text-figures, to identify this tick until such time as my friend, D. C. Swan, is demobilized and returns to civilian duties and his work on Australian ticks.

Neotype, K67638, in the Australian Museum, Sydney. There are thirteen other specimens also in the Museum Collection.

*HAEMAPHYSALIS MERAUKENSIS*, new name.

Krijgsman and Ponto gave the name of *novae-guineae* to a species of *Haemaphysalis* in 1932 (*Veeartsenijk. Meded.* No. lxxix, 17) quite overlooking the fact that Hirst in 1914 (*Trans. Zool. Soc. Lond.*, xx (10): 328, fig. 16) had used the same specific name also for a species of the same genus. Therefore a change of name is necessary.





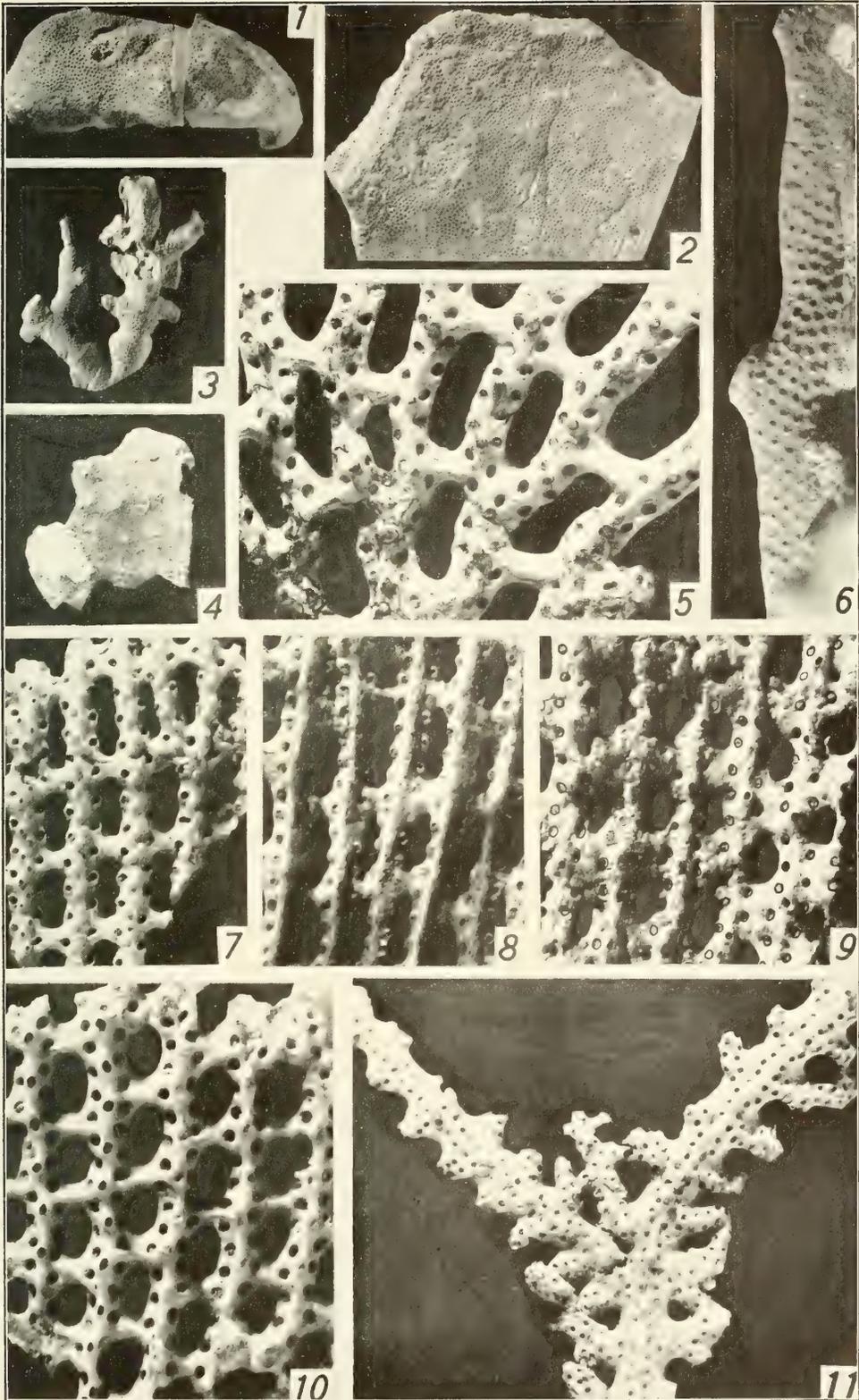
Petrology of the Hartley District.





Alex G. Hamilton





Eryozoa from the Permian of Western Australia.



NOTES ON AUSTRALIAN BOARMIIDAE AND OENOCROMIDAE (LEPIDOPTERA)  
WITH DESCRIPTIONS OF NEW SPECIES.

By the late G. M. GOLDFINCH.

(Communicated by Dr. A. Jefferis Turner, F.R.E.S.)

[Read 27th September, 1944.]

It had recently been my intention to confine this paper to descriptions of new Australian Geometrites, and the diagnosis of such new genera as was necessary, but having recently had the privilege of studying the types of the species of Boarmiidae described by Mr. Lower, and now in the possession of the South Australian Museum, it would now seem advisable to place on record the observations there made. In this connection, I take the opportunity of tendering my thanks to the Director of the South Australian Museum for the opportunities of study afforded to me, and Mr. N. B. Tindale, of the Museum Staff, for their generous assistance in the matter of locating types, etc. Furthermore, I wish to thank Dr. A. J. Turner for the never-failing encouragement and assistance extended to me, and also Mr. G. Lyell for the opportunity of examining his extensive collection and for the gift of many valuable specimens. The synonymy given in this paper is not intended to be complete, but may be considered as supplementary to that recorded by the late Mr. E. Meyrick and Dr. A. J. Turner in their various papers.

Family BOARMIIDAE.

ANISOGRAPHE DISSIMILIS Warr.

*Orsonoba euryscopia* Low., *Trans. Roy. Soc. S. Aust.*, 1905, p. 178, is a synonym.

MEDASINA STRIXARIA Gn.

New South Wales: Allyn R. in December. In dense rain-forest, hiding in the dead fronds of "Birds-nest" ferns.

MEDASINA MAURARIA Gn.

Lepid., ix, p. 216. Feld., Pl. 126, figs. 18, 19. Hamps. Moths Ind., iii, p. 285.

North Queensland: Mackay. Three specimens in the South Australian Museum ex Lower Collection.

DYSBATUS SINGULARIS Butl.

*Anomoctena trisecta* Turn., *Proc. Linn. Soc. N.S.W.*, 1917, p. 319. *Stibaroma stenodesma* Low., *ibid.*, 1899, p. 87. *Pachyptila doliopa* Low., *Trans. Roy. Soc. S. Aust.*, 1903, p. 193.

ECTROPIS ODONTOPHORA Turn.

North Queensland: Meringa (Cairns district) in November. Apparently attached to *Tristania*, on the pinkish bark of which it is well concealed.

ECTROPIS AGANOFA Meyr.

This is a true *Ectropis*. The antennal joints are unusually long and at first sight do not appear to have two pairs of pectinations.

ECTROPIS CALIDA, n. sp.\*

♂. 28 mm. ♀. 33 mm. Head smooth; face dark brown, somewhat paler below middle; vertex ochreous. Palpi rather short, brown. Antennae bipectinate almost to apex, ochreous barred with brown. Thorax ochreous with scattered brown scales towards tips of patagia and posterior margin. Abdomen ochreous with a divided fuscous bar on posterior edge of each segment, the first three segments with an anterior brown bar; tuft ochreous, towards base fuscous. Legs, anterior and median pairs fuscous above, whitish beneath; tarsi ringed with whitish; posterior pair ochreous-whitish sparsely

\* The Goldfinch Collection is now in possession of The Australian Museum.

irrorated with brown scales, little dilated. Forewings triangular, costa somewhat curved towards base, thence almost straight to apex, hind margin evenly bowed, somewhat waved; 10 and 11 coincident from cell before angle and free; reddish-brown except costal and apical areas, which are ochreous, sparsely irrorated with fuscous scales; markings fuscous; first line very fine, from costa at one-third, curved evenly outwards beneath costa to cell, thence almost straight to dorsum at one-fourth; second line from costa beyond two-thirds, very fine, somewhat dentate beneath costa, thence diagonal and almost straight to dorsum at about one-half; a short brownish shade from costa to second line beneath costa; subterminal line indicated only by a few whitish scales between veins; cilia brown barred with ochreous, at apex ochreous. Hindwings waved; ochreous strigulated with reddish; first line straight, reddish, from dorsum beyond one-third, not reaching beyond one-half; second line from dorsum to costa before apex, slightly angled outwards beneath costa, black, closely followed by a narrow reddish-brown shade to middle; the terminal area from below apex to above tornus reddish-brown; subterminal line indicated by a few whitish scales between veins; terminal line as in forewings; cilia as in forewings, but with traces of a fuscous central line.

In the female the ochreous areas in both fore- and hindwings are paler, almost whitish. In the forewing the ante-apical shade forms a reddish-brown patch, and in the hindwing the basal area is mostly reddish-brown, and there is a faintly indicated discal dot. The male antennae place this species in the *excursaria* group.

New South Wales: Mittagong in April; two specimens in Eucalyptus forest at light.

ECTROPIS LIGNEA, n. sp.

♂, ♀. 28–30 mm. Head smooth; face fuscous; vertex greyish-fuscous. Palpi rather short; fuscous. Antennae bipectinate-fasciculate almost to apex. Legs long and very slender; anterior and median pairs fuscous, tarsi whitish-ringed; posterior pair whitish; tibiae somewhat dilated. Abdomen fuscous. Forewings triangular, costa almost straight to apex, termen bowed, crenulate; 10 and 11 long-stalked and free; pale fuscous irrorated with fuscous scales; markings obscure, fuscous; first line very fine, from dorsum near base, outwardly oblique to beneath costa at about one-third; second line from dorsum at one-half, outwardly oblique and somewhat sinuate to costa before apex, indicated beneath costa by a series of small black dashes followed by a slender parallel fuscous shade; an obscure rather broad fuscous shade from termen below apex inwards to cell, passing through second line; subterminal line faintly indicated with whitish scales between veins; two fuscous dots before apex; a terminal black line thickened into dots between veins; a fine black dot at end of cell; cilia pale fuscous indistinctly barred with darker. Hindwings crenulate; colour as in forewings; first line obscure, short, not reaching into cell; second line obscure, slightly waved, hardly reaching costa before apex; subterminal line and cilia as in forewings; a small black discal dot. In the female the basal and supra-tornal areas of the forewings are sometimes more or less suffused with whitish.

New South Wales: Mittagong in April and November; two specimens taken in Eucalyptus forest at light.

ECTROPIS AGANOPA MEYR.

This is a true *Ectropis*. The antennal joints are unusually long, and at first sight do not appear to carry two pairs of pectinations.

SCIOGLYPTIS LITHINOPA MEYR.

This species apparently does not occur in Sydney. It has been confused with *Syneora hemeropa* Meyr., and the Sydney record may be disregarded.

SCIOGLYPTIS TAENIOTA TURN.

In the forewing 10 and 11 are long-stalked from the cell and sometimes connected with 12 by a long bar.

SYNEORA SILICARIA GN.

The species described by Meyrick under this name is *Boarmia mundifera* Wlk. I here describe the species, which I believe to be the true *B. silicaria* Gn.

♂, ♀. 40–46 mm. Head smooth, face slightly rounded; black with a central transverse pure white bar, vertex purplish. Palpi short, hardly projecting beyond face, terminal joint obtuse; brownish-fuscous. Antennae bipectinate, apex simple. Thorax with small posterior bifid crest; purplish-grey with a strong black transverse anterior line, and a similar line posterior to the thoracic crest. Abdomen grey, a distinct black line across first segment, and traces of black on second and third segments. Legs, anterior and middle pairs greyish-fuscous; posterior pair white, tibiae somewhat dilated. Forewings triangular, costa almost straight, apex rounded, termen evenly rounded, waved; 10 and 11 separate from cell, 11 anastomosing with 12, 10 free; fovea present; purplish-grey; markings black and brown; a short longitudinal black streak; a strong black line obliquely from dorsum near base to lower margin of cell at origin of vein 2, preceded by an obscure reddish-brown shade; second line from dorsum at one-half, twice sinuate, to vein 6 beyond cell, somewhat thickened in middle, and twice moderately bent, followed by an obscure reddish-brown shade; a subterminal waved line from below costa before apex to dorsum before tornus, whitish, bordered posteriorly by a few blackish scales; an oblique black line from termen below apex to origin of subterminal line; cilia purplish-grey; the area between first and second lines and extending to apex is somewhat paler and less purplish than the remainder of the wing. Distinguishable from *B. mundifera* by its larger size, purplish colour, differently marked face, and absence of the groove in the hindwing of the male.

New South Wales: Sydney (National Park) in August and September; Mittagong in April. Attached to *Leptospermum*, on the purplish bark of which it is well concealed.

SYNEORA NIGRILINEA, n. sp.

♂. 36 mm. Head with frons slightly projecting, rounded; ochreous grey. Palpi short, second joint hairy beneath; greyish-fuscous. Antennae bipectinate, apex simple, pectinations 4. Thorax with a small bifid posterior crest; ochreous; an indistinct transverse anterior black line; patagia black-barred in middle, and with a black bar immediately anterior to crest. Abdomen ochreous, a double black dorsal dot on second and third segments. Legs, anterior and middle pairs fuscous irrorated with ochreous; posterior pair ochreous sparsely irrorated with fuscous. Forewings triangular, costa almost straight, apex gently rounded, termen bowed, moderately oblique, waved; 10 and 11 stalked from near end of cell and free; ochreous irrorated with black and white scales; markings black; first line from costa beyond one-fourth, forming a very acute angle inwards beneath costa, thence almost straight to dorsum near base; an indistinct line from costa at about one-half, straight to dorsum at one-fourth, forming a darker dot on lower margin of cell; an obscure oblique waved line from costa before apex to dorsum beyond one-half, thickened in middle, and followed posteriorly by a narrow brownish shade connected with costa at three-fourths by a series of three black dots; a dentate whitish subterminal line from apex to dorsum at two-thirds, edged anteriorly and posteriorly by an obscure fuscous shade; a fuscous suffusion diagonally inwards from termen beneath apex; a fine black terminal line, deeply indented at termination of each vein; a fine black discal dot; cilia ochreous. Hindwings rounded, crenulate; ochreous irrorated with black and white scales; first line from dorsum before one-half, reaching upper margin of cell; second line from dorsum beyond middle, not reaching costa, almost straight, followed posteriorly by a narrow brownish shade; a narrow waved white subterminal line from tornus to apex, edged anteriorly and posteriorly by a fuscous shade; terminal line, discal dot, and cilia as forewings.

West Australia: Busselton; one specimen.

SYNEORA EMMELODES TURN.

New South Wales: Pt. Macquarie and Mittagong in November and December. Attached to ti-tree and not uncommon.

Gen. PROTOSYNEORA, n.g.

Frons with a strongly projecting rounded corneous prominence. Tongue well developed. Palpi rather long, terminal joint with rough scales above and beneath. Antennae of male serrate, minutely ciliated. Thorax with a short bifid posterior crest.

Abdomen smooth. Femora smooth; posterior tibiae slightly thickened. Forewings with fovea absent; 10 and 11 usually separate from cell and free. Hindwings normal. Apparently allied to *Syneora*, but less specialized. Of five males, in three 10 and 11 are separate from cell and free, in one coincident and free, in one separate and free in one wing, and connate in the other.

*PROTOSYNEORA SORDIDA*, n. sp.

♂. Head and palpi grey slightly ochreous-tinged, with scattered black scales. Antennae whitish with scattered black scales. Thorax ochreous-grey, posterior crest with blackish scales on sides. Abdomen greyish; anal claspers densely clothed with very fine ochreous hairs; tuft grey. Legs whitish with scattered fuscous scales; anterior tarsi ringed with fuscous and whitish. Forewings triangular costa straight to apex, apex rounded, termen bowed; whitish-grey irrorated with extremely fine fuscous dots, the amount of irroration varying rather widely; lines almost obsolete; usually a small outwardly oblique mark on costa at one-sixth, and slightly beyond usually a similar mark; a very obscure waved line from costa at five-sixths to dorsum at three-fourths; this line is hardly distinguishable itself, but the area beyond it is usually more heavily irrorated; usually a more or less indistinct fuscous streak from termen beneath apex to second line beneath costa; sometimes a minute discal dot; a series of terminal fuscous dots between veins; cilia white barred with pale fuscous opposite veins. Hindwings grey, towards base whiter; a few fuscous scales along dorsum indicating first and second lines; terminal area darker grey; a minute discal dot; subterminal dots and cilia as forewings. Beneath forewings whitish irrorated with fuscous, more heavily towards base of costa; a distinct discal dot; a pale fuscous apical blotch extending to midtermen. Hindwings similar, but fuscous blotch extending to tornus.

South Australia: Mt. Painter, Flinders Rge. (H. G. Stokes). Type in South Australian Museum, where there is a series.

*BOARMIA CORTICOLA*, n. sp.

♂. 42 mm. Head smooth, face white, slightly brownish-tinged, a few long grey scales tipped with brown projecting between antennae. Palpi moderate, porrect, hairy beneath; brown, towards base beneath white, apex of terminal joint white above. Antennae bipectinate, pectinations 6, apex simple. Thorax smooth; grey obscurely mottled with darker. Abdomen grey, with two fuscous dots on each of first three segments. Legs, anterior and median pairs black, broadly ringed with snow-white; posterior pair white. Forewings triangular, costa almost straight, apex rather broadly rounded, termen evenly bowed; 10 and 11 long-stalked from cell, the stalk anastomosing with 12, 10 anastomosing with the stalk of 8+9 beyond 7; white mottled with pale fuscous, slightly greenish-tinged, pattern very confused and ill-defined; a sub-basal obscure fuscous line from costa near base, slightly outwardly curved below costa to dorsum near base, closely followed by a parallel fuscous line to dorsum at one-fourth; a large fuscous blotch from costa at one-half, containing darker scales representing discal dot; from its lower extremity arises a dentate rather slender line to dorsum at one-half; a slender dentate whitish line from costa before three-fourths to dorsum before three-fourths, edged on both sides with fuscous, the veins on anterior side marked with dark fuscous spots; a narrow dentate whitish subterminal line from costa before apex towards tornus becoming lost in ground-colour; terminal area blotched with fuscous and divided in middle by a snow-white irregular transverse bar; a terminal series of black dots on veins; cilia pale fuscous indistinctly barred with white. Hindwings evenly rounded, slightly crenulate; white mottled with pale fuscous; an obscure fuscous line from costa at one-half to a discal blotch, thence to dorsum at one-half; a slender dentate white line from costa before apex to dorsum below middle; discal blotch almost rectangular, edged on both sides with fuscous; a narrow obscure dentate whitish subterminal line from apex to tornus, becoming lost in an area of ground-colour in middle, edged clearly anteriorly and obscurely posteriorly with fuscous; a subterminal series of dark fuscous dots on veins; cilia pale fuscous indistinctly barred with whitish, towards apex white. The whole of the ground-colour in both wings is scattered with

small pale fuscous blotches containing darker fuscous scales, and tending to form strigulae along the costa of forewing.

New South Wales: Barrington Tops (5,000 ft.) in January; Allyn River in December; Stanwell Park, near Bulli; three specimens taken in dense rain-forest at rest on mossy tree trunks.

BOARMIA DRIOPHILA, n. sp.

♂, ♀. 25 mm. Face flat, head smooth, grey, slightly purplish-tinged. Palpi moderate, rather densely clothed to apex with long scales, porrect; ochreous, towards base whitish. Antennae rather short, joints unusually long, in male bipectinate, apex simple, pectinations very long (10). Thorax smooth; purplish-grey with a broad dark fuscous transverse mark at posterior edge. Abdomen purplish-grey. Legs, anterior and middle pairs fuscous; posterior pair ochreous-whitish irrorated with pale fuscous; tibiae not dilated. Forewings triangular costa evenly bowed to apex, apex rounded, termen almost straight; 10 and 11 coincident and free from near angle of cell; fovea present; purplish-grey; markings dark brown, sometimes more or less obsolete; an outwardly oblique line from costa at one-fourth to lower margin of cell, thence gently curved inwards to dorsum near base; the enclosed space sparsely irrorated with dark brown; second from costa at one-half, sometimes almost obsolete, curved outwards beneath costa, thence almost straight to dorsum at one-third; third line from costa at three-fourths, thrice slightly curved inwards, the central curve filled in with black posteriorly and with a faint reddish-brown suffusion; subterminal area sparsely irrorated with fuscous; the space between second and third lines sometimes containing an obscure reddish-brown line not reaching cell; cilia grey. Hindwings purplish-grey sparsely irrorated with fuscous; a short transverse fuscous mark from dorsum near base; three parallel reddish-brown lines from middle of dorsum not reaching costa, the first and third containing black scales, the middle line sometimes obsolete; cilia grey.

New South Wales: Sydney (National Park) in September and October; Mittagong in March. Attached to *Leptospermum*; taken in company with *Boarmia pallidisaria* Meyr., which, though smaller, it somewhat resembles.

BOARMIA LITHINA WARR.

*B. eudeta* Turn. is, I think, without doubt a heavily marked female of this species. I have taken this together with the normal form in the Cairns district.

AMBLYCHIA SUBRUBIDA WARR.

*Nov. Zool.*, 1896, p. 300.

*Elphos hypocallistis* Low., *Proc. Linn. Soc. N.S.W.*, 1898, p. 44, is a synonym.

GEN. NICETERIA TURN.

*Trans. Roy. Soc. S. Aust.*, 1929, p. 297.

NICETERIA MACROCOSMA LOW.

The male antennae are unipectinate. The arrangement of scales towards the base of the forewings, that is, exceptionally long scales in transverse straight lines overlapping like tiles, is remarkable.

NADAGARA XYLOTREMA LOW.

*Boarmia xylostroma* Low., *Trans. Roy. Soc. S. Aust.*, 1903, p. 29. *Nadagara argyrosticha* Turn., *Proc. Linn. Soc. N.S.W.*, 1919, p. 285.

IDIODES STICTOPLEURA, n. sp.

♀. 42 mm. Face smooth, a slight projection of white scales between the palpi; white, vertex dark brown, posteriorly grey. Palpi rather long, slightly rough beneath, terminal joint short; reddish-brown. Thorax grey. Abdomen grey, shading to ochreous beneath. Legs ochreous with scattered fuscous scales; posterior tibiae dilated. Forewings triangular, costa curved towards base, thence almost straight to apex, apex acute, termen waved, more or less blunt projections on veins 6 and 4; 7, 8, 9, 10 stalked, 11 from cell and free; grey, somewhat brownish-tinged strigulated more or less thickly with pale

brown; costal edge black barred with snow-white; first line from costa before one-third to dorsum at one-third, bent above dorsum, brown; second line from costa at five-sixths, slightly bent outwards below costa, thence straight to dorsum before two-thirds, bordered posteriorly by a silvery grey line; subterminal line indistinct, obscurely waved, silvery-grey; subterminal area suffused with silvery-grey; cilia brown. Hindwings with termen waved and somewhat indented in middle; colour and strigulations as in forewings; a straight brown line from dorsum beyond middle not reaching middle of costa; cilia brown. Underside ochreous-brown thickly strigulated with fuscous; in forewing first line absent; second line not reaching costa; in hindwing first line as on upper surface; a second line parallel to termen, not reaching dorsum. In the absence of the male it is uncertain whether this species is correctly placed.

New South Wales: Woodford, Blue Mts.; one specimen in January at light.

Gen. PAUROMOMA Low.

Forewings with 10 and 11 long-stalked from cell, 10 anastomosing with stalk of 8+9 beyond 7.

Turner's description of the genus is not in agreement with Lower's original description, which, though awkwardly expressed, is correct.

Gen. AMPHICROSSA Low.

Forewings with 10 and 11 long-stalked from cell, 10 anastomosing with stalk of 8+9. Lower's description of the forewing venation is not correct.

Gen. AMELORA Meyr.

*Angelia* Low. is a synonym. The distinction between *Amelora* and *Angelia*, as proposed by Turner, would have been perfectly sound, but unfortunately the type of *Angelia* as nominated by Lower was *A. tephrochroa* Low., in which the frontal prominence is merely rounded. It will therefore be necessary to propose a new genus to contain those species with a horizontal horny spatulate frontal process.

Gen. LOWERIA, n.g.

Frons with a horizontal corneous spatulate frontal process. Tongue well developed. Palpi moderate or rather short; second joint roughly hairy; terminal joint minute. Antennae of male bipectinate to apex. Thorax sometimes with a small anterior triangular crest. Posterior tibiae with two pairs of spurs, in male dilated. Forewings in male with a basal fovea; 10 and 11 arising from cell by a common stalk, which is connected by a bar with 12, 10 anastomosing with 9; hindwings with 6 and 7 separate, connate, or stalked. Type, *L. heteropa* Low.

AUTHAEMON PURPUREA, n. sp.

♂, ♀. 36-38 mm. Head and face purplish-brown. Palpi in male 3 and one-half, in female 3; terminal joint in male one-fourth, in female one-sixth; purplish-brown. Antennae fuscous. Thorax purplish-fuscous. Abdomen purplish-grey. Legs purplish-fuscous irrorated with whitish; tarsi dark fuscous with whitish rings. Forewings triangular, costa arched at base, thence straight, apex acute, somewhat produced, termen strongly bowed, scarcely oblique; purplish-brown with scattered whitish scales along extreme costal edge; first line indicated by three fuscous dots, each edged anteriorly with white; an obscure fuscous discal spot; an obscure line of fuscous dots each edged posteriorly with white from five-sixths costa to three-fourths dorsum; space between veins sparsely irrorated with fuscous and greyish; a terminal series of yellowish-white dots; cilia purplish-brown. Hindwings with termen rounded, slightly waved; rather pale fuscous; a post-median line of dots as in forewings, but less distinct; terminal dots and cilia as forewings. Distinguished from other species of the genus by the purplish-brown colour, absence of whitish costal streak, and the yellowish terminal dots.

New South Wales: Mittagong; one male in February; in April one damaged female.

Gen. LOPHOTHALAINA, n.g.

Face smooth, rounded, slightly projecting. Tongue well developed. Palpi short, porrect, rough-haired; terminal joint very short. Antennae in male laminate, minutely ciliated. Thorax with a tall anterior crest; hairy beneath. Femora smooth; posterior

tibiae somewhat dilated, with a long pencil of hairs on inner side. Forewings without fovea; 7, 8, 9, 10 stalked from before angle of cell, 11 from cell and free. Allied to *Thalaina*, from which it differs in 11 being free from cell, and in the thoracic crest. Type, *L. habrocosma* Low.

LOPHOTHALAINA HABROCOSMA LOW.

New South Wales: Mittagong in April. Attached to *Leptospermum*, on the bark of which this elegant species is well concealed, the yellow hindwings being completely hidden in the rest attitude.

THALAINA INSCRIPTA Wlk.

*T. hieroglyphica* Low. is a synonym. The type is a freshly emerged and only partially expanded cripple.

FISERA NICHOLSONI, n. sp.

♂. 58-66 mm. Face with strong rounded prominence; head greyish-brown. Palpi reddish-brown with scattered grey scales. Antennae brick red. Thorax with narrow keel-like median crest; greyish-brown. Abdomen brick red. Legs, anterior and middle pairs fuscous; posterior pair brick red. Forewings elongate-triangular, costa arched towards base, thence somewhat bowed to apex, apex acute, sometimes produced, termen bowed, waved, scarcely oblique; reddish-brown densely irrorated with fuscous and grey particularly along costa towards base; first and second lines indicated on dorsum at two-fifths and four-fifths, made heavier by irroration with black; cilia reddish-brown. Hindwings with termen unevenly rounded, waved, tornus somewhat produced; ochreous-red; a curved fuscous suffusion from beneath costa near apex, narrowing towards middle of wing, sometimes almost obsolete; cilia ochreous-red. Superficially like a *Stathmorrhopa*, but the apical hooks, though short, are present.

New South Wales: Barrington Tops (5,000 ft.). Named after the captor, Dr. A. J. Nicholson.

STATHMORRHOPA POLYSTICHA, n. sp.

♂. 58 mm. Head and thorax grey, becoming paler posteriorly. Antennae grey; pectinations yellow. Thorax densely hairy beneath. Abdomen greyish-white; tuft white, greyish towards base above. Legs white; tarsi grey. Forewings elongate-triangular, apex pointed, slightly produced, termen strongly bowed; silvery-grey sparsely irrorated with black; two fuscous streaks from near base of cell terminating in a fuscous dot at end of cell; fuscous streaks between all veins, excepting those terminating on costa; cilia fuscous, becoming paler towards tornus, tips white. Hindwings with termen unevenly rounded; basal area white; terminal area broadly pale fuscous; a small pale fuscous discal dot; cilia white.

New South Wales: Mittagong in April; four specimens beaten from *Eucalyptus* saplings at night.

Gen. MEGAZANCLA, n.g.

Head smoothly scaled, face with a rounded prominence somewhat flattened and depressed at apex. Palpi moderate, porrect; second joint clothed with long scales beneath; terminal joint short, smooth. Antennae of male bipectinate at base (apex broken), in female simple. Thorax smooth, densely hairy beneath. Femora and coxae densely hairy; anterior tibiae with very long apical hooks; posterior tibiae dilated; all spurs present; tarsi spined. Abdomen smooth; uncus extraordinarily long and hooked. Forewings without fovea; 11 from cell anastomosing with 12, 10 from cell anastomosing broadly with stalk of 8+9 beyond 7; 7, 8, 9 stalked from before angle of cell. Hindwings normal.

MEGAZANCLA CINEREA, n. sp.

♂. 38-40 mm. Head and thorax smooth; grey, in female slightly pinkish-tinged anteriorly. Abdomen ochreous-grey. Legs grey; posterior pair whitish. Forewings triangular, costa somewhat bent towards base, thence almost straight to apex, apex pointed, termen almost straight; grey slightly brownish tinged, with numerous trans-

verse strigulations entirely due to scale arrangement and not to colour gradation; cilia grey, white-tipped. Hindwings evenly rounded; dark greyish-fuscous becoming paler towards base; cilia grey, white-tipped. Beneath forewings smoky fuscous, somewhat paler along costa and termen, hindwings pale grey, a large fuscous suffusion towards termen, not reaching costa.

West Australia: Kojarena, near Geraldton, in September; one male and one female (the former in poor condition) taken at light by Dr. G. A. Waterhouse. The arrangement of scales in the forewings is peculiar and is similar to that in *Euzora collucens* Luc. in the Lymantriidae. It produces a glistening effect.

Gen. NYCTILAMPES, n.g.

Frons flat, rough-scaled. Tongue well developed. Palpi moderate, porrect, densely rough-scaled; terminal joint rather long, smooth-scaled. Antennae bipectinate almost to apex. Thorax smooth, densely hairy beneath. Abdomen without crest. Forewings in male without fovea; 7, 8, 9 long-stalked from before angle of cell, 10 from cell anastomosing with 9, 11 from cell and free. Hindwings normal.

NYCTILAMPES FUNEREA, n. sp.

♂. 56 mm. Head purplish-fuscous, tips of scales reddish. Palpi brownish. Antennae brown. Thorax smooth; purplish-brown, tips of scales reddish. Abdomen grey. Legs brown. Forewings elongate-triangular, costa almost straight, apex pointed, somewhat produced, termen strongly bowed, slightly crenulate; purplish-fuscous heavily irrorated with greyish; an outwardly bifurcated black streak along discal fold; black streaks between veins, becoming weaker towards apex; cilia purplish, tips whitish. Hindwings unevenly rounded, slightly waved; fuscous-brown, paler towards base, darker towards apex; cilia grey with darker central line.

New South Wales: Mittagong in March and April; two taken at light. There is a third specimen in the National Museum, Melbourne.

Gen. ANOCHTHERA, n.g.

Frons rounded, prominent. Tongue well developed. Palpi moderate, rough-scaled; terminal joint short. Antennae of male bipectinate to apex. Thorax smooth; densely hairy beneath. Abdomen smooth. Femora hairy; posterior tibiae not dilated. Forewings of male without fovea; 7, 8, 9, 10 stalked, 11 from cell, connected with 12 by a bar and then anastomosing with 10. Hindwings normal. Allied to *Stathmorrhopa*, from which it differs in the absence of a thoracic crest.

ANOCHTHERA INDISTINCTA, n. sp.

♂. 48 mm. Head and palpi brown. Antennae reddish-brown. Thorax brown. Abdomen paler. Legs brown; tarsi fringed with whitish. Forewings elongate-triangular, costa arched towards base, thence straight, apex round-pointed, termen bowed, slightly crenulate; dull brown irrorated with whitish and with sparsely scattered brown transverse strigulae; a small brown discal spot; area towards base of costa somewhat darker, cilia brownish. Hindwings with termen unevenly rounded and slightly waved; pale brown, becoming paler towards base; cilia brownish. Resembles *Stathmorrhopa beggaria* Gn., but the forewings are less elongate and the hindwings narrower.

New South Wales: Probably from Sydney or Newcastle; one specimen from Coll. Parkes.

Family OENOCROMIDAE.

DICHROMODES IMPLICATA, n. sp.

♂, ♀. 30-32 mm. Head smooth, face rounded, somewhat prominent; fuscous irrorated with white. Palpi rough-scaled posteriorly; fuscous with a few white scales along upper edge; beneath, snow-white towards base. Antennae in male unipectinate; fuscous. Thorax smooth; fuscous irrorated with white. Abdomen ochreous-whitish. Legs fuscous; posterior pair irrorated with grey. Forewings triangular, costa somewhat bent towards base, apex blunt, termen evenly rounded; white more or less densely irrorated with black; markings black; an indistinct short erect black mark from dorsum near base

not reaching costa, closely followed posteriorly by a sinuate black line reaching costa at one-fourth; a black line from costa at two-fifths to dorsum at two-fifths angled outwards at each vein and twice in disc, preceded anteriorly by a broad band of white more or less free from black irroration; a rather broad, dentate, subterminal line from costa before apex to tornus, black somewhat suffused anteriorly with white, and edged posteriorly with white; between this and termen an obscure fuscous shade from beneath costa not reaching tornus; black lunules between veins; an oval black spot at end of cell; occasionally the veins crossing the median area are black; cilia white broadly barred with black at ends of veins. Hindwings in male ochreous-grey, in female yellow; a greyish suffusion along termen; an obscure sinuate greyish line from dorsum before tornus to costa before apex, less distinct in female; a short line inwards from tornus followed by a whitish shade; a subterminal line more or less interrupted on veins; cilia as forewings.

New South Wales: Mt. Kosciusko (5,000 ft.) in December; very abundant in the moorland swamps.

DICHROMODES SIMPLA, n. sp.

♂, ♀. 14 mm. Head smooth, rather flattened, eyes prominent; white. Palpi long (2 and one-half), porrect, rough-scaled; beneath, white. Antennae in male unipectinate; white. Thorax, abdomen, and legs white. Forewings triangular, costa arched towards base, thence somewhat sinuate to apex, apex rounded, termen slightly bowed; white, markings almost absent; a few fuscous scales towards base of costa; a fuscous mark on costa before middle; a dot on cubitus and one on anal vein at about one-third; a very fine indistinct dentate line from costa before apex to two-thirds dorsum; cilia white with a few fuscous scales. Hindwings evenly rounded; white; cilia white.

West Australia: Busselton; three of each sex in October; taken pressed close to surface after stripping sheets of bark from ti-tree.

Gen. NEOLISSOMMA, n.g.

Head rounded, densely hairy; face smoothly rounded, somewhat prominent. Tongue present. Palpi with second joint short, hairy; palpi hairy; second joint rather short; terminal joint long. Antennae in male unipectinate. Thorax with a trifid posterior crest. Abdomen smooth. Anterior tibiae without apical hook; posterior tibiae with two pairs of spurs. Forewings deeply crenulate; 11 from cell and free, 10 from cell connected with stalk of 8+9 by a bar, 7, 8, 9 long-stalked from angle of cell, 6 connate. Hindwings with 8 approximated to cell to beyond middle, 6 and 7 connate, 5 from near 6, and 3 and 4 approximated at origin. Differs from *Ophiographa* Prout in the smoothly rounded face and presence of two pairs of spurs on posterior tibiae, and in vein 10 being free; from *Lissocraspeda* Prout by the face and tibial spurs and the presence of the tongue; from *Lissomma* Warr. in the absence of a claw on the anterior tibiae and in 10 being free.

NEOLISSOMMA GRACILIS, n. sp.

♂. 28 mm. Head grey. Palpi with long hairs projecting beneath. Thorax densely hairy beneath; grey, beneath somewhat pinkish anteriorly, crest darker grey. Abdomen grey; each segment white posteriorly. Legs with femora hairy, tibiae smooth; grey; anterior and middle tibiae tinged with pink. Forewings triangular, costa somewhat bowed towards base, thence slightly curved inwards to before apex, apex pointed, termen strongly bowed, dentate; grey sparsely irrorated with dark red; markings white; first line from costa before one-fourth, twice bent inwards to dorsum at one-third, the lower curve entirely, the upper somewhat less, edged posteriorly with dark red; the apices of terminal dentations dark grey; hindwings somewhat elongate, narrow, termen deeply dentate; grey; a fine sinuate whitish line from dorsum at two-thirds to costa before apex, preceded anteriorly by a dark grey line; cilia white. Beneath forewings grey; first line absent. Hindwings greyish-white; a dark reddish-brown line from costa before apex, not reaching dorsum; a large oval dark reddish-brown blotch in median area, surrounded by a brownish-ochreous shade with scattered crimson scales.

West Australia: Kojarena, near Geraldton, in September; five specimens taken at light by Dr. G. A. Waterhouse.

## THE GEOLOGY OF THE ALBURY DISTRICT.

By GERMAINE A. JOPLIN, B.Sc., Ph.D., Linnean Macleay Fellow of the Society  
in Geology.

(Plates vi-viii; Three Text-figures.)

[Read 27th September, 1944.]

## I. Introduction.

Albury is situated on the northern bank of the Murray River at a distance of 399 miles by rail from Sydney and 191 miles from Melbourne. It is an important railway terminus and the centre of a wealthy wool-growing industry. Mining is of little importance at present, though numerous shafts about the district indicate spasmodic mining activity during the past 90 years. Except for brief reports on these ventures and a map and section (see Fig. 3) in connection with experimental bores over two Tertiary leads, nothing has been published on the geology of the Albury district.

South of the Murray River, however, there has been active mining for gold and tin and there are numerous detailed maps and many economic reports dealing with the mineral fields. Furthermore, extensive studies have been made on the metamorphic belt of North-eastern Victoria, first by Howitt (1884-1889) and later by Tattam (1929). As pointed out by Browne (1929), the Albury schists and phyllites form the northern continuation of those described by Howitt, and, like the Victorian schists, they are of Ordovician age.

Although the main reason for undertaking geological work at Albury was to make a petrological study of the Ordovician rocks, it is obvious that detailed work of this nature cannot be carried out until the region has been mapped and the general geology described; so the present paper is an attempt to lay the foundation for a later one on the petrology of the Ordovician rocks which will be a continuation of the series entitled "Petrological Studies in the Ordovician of New South Wales" of which parts i and ii have already been published (Joplin, 1942, 1943). In the circumstances it was deemed unnecessary to spend a great deal of time over details which do not affect the main Ordovician problems, and the accompanying map (Plate vi), though fairly accurate, is only of a reconnaissance nature.

## II. GENERAL GEOLOGY AND PHYSIOGRAPHY.

Reference to the map will show that the Ordovician rocks, so far mapped, extend from just west of Moorwatha Trigonometrical Station, near Bungowannah, eastwards to the Bowna Arm of the Hume Reservoir—a distance of some 20 miles. Along their southern margin they are overlain by the Murray River alluvium, and although the western boundary has not yet been traced, it is known that they disappear beneath the alluvium of the Western Plains just beyond the western edge of the map. On the north and north-east the Ordovician rocks are overlain by rhyolites, porphyries and tuffs of (?) Lower Devonian age and by Upper Devonian sediments. Along their northern outcrop they are invaded by porphyritic granites, and near Hume Weir, on the Hawksview Estate, there is a mass of fine even-grained granite. These younger granites are possibly of Middle Devonian or of Kanimbla age. The Ordovician rocks consist mainly of schists and granitized schists laced with small sills of pegmatite (Fig. 1), and in the northern part of this folded series, two large sills or phacoliths of acid granite occur. Gneisses, much contaminated, crop out on the bank of the Murray River just west of the town of Albury, and along the shore of the Bowna Arm of the Hume Reservoir.

Several different types of topography are developed in the Albury district: first, the extremely flat *terrain* of the alluvium both in the vicinity of the river and to the

west and north-west as the plain country is approached; second, the mountainous or hilly country of the Ordovician schists and younger granites; and third, the undulating country with a deep soil cover and occasional outcrops of schist and porphyry. A ridge of low hills bordering the western shore of the Bowna Arm of the Reservoir does not fall precisely into any of these categories and will be referred to later. To the north of Table Top, the Yambla Range, capped by Upper Devonian sediments dipping west, gives rise to a cuesta topography with steep cliffs on the east and gentle slopes on the west (Plate viii, fig. 9).

The Murray River (Plate vii, fig. 1) flows in a mature valley and follows a sinuous course with numerous anabranches and billabongs. The town of Albury is built on the river alluvium at a height of 530 ft. above sea-level. The alluvial flats lie between the 500 ft. and 600 ft. contours, and a terrace is often present at the 600 ft. level between the flat and undulating *terrains*. The river flats are mainly dairying country.

To the north-north-west of Albury, about Jindera, the country is also flat, but at a higher general level—about 750 to 800 feet. Wheat growing and mixed farming are the main industries of this *terrain*, which appears to be part of the Western Plain alluvium (Plate vii, fig. 2).

The undulating country lies between the 600 ft. and 750 ft. levels and extends through the Parishes of Albury, Thurgona, Bowna and Yambla (Plate vii, figs. 3, 4 and 5). A good deal of it is under wheat or vine cultivation and the remainder is heavily grassed grazing country. In the Tallangatta area of Victoria, Easton (1915–1917) has mapped Pliocene alluvials above the present river alluvium, and it is possible that some of the so-called undulating country is of this origin, but neither gravel nor sand has been observed, and the few scattered outcrops of this *terrain* indicate that the deep soil has been derived from Ordovician schists, and further north from later porphyries and tuffs. The soil appears to be a deep red loam and pisolitic soils are very common throughout the area. It seems impossible to make any distinction between the soil derived from the schist and that derived from the porphyry. Nevertheless, orchards and vineyards are more frequent in the southern part of the area and wheat is grown on the soil presumably derived from porphyry.

The mountainous or hilly country rises very abruptly above the alluvial flats or gently undulating country (Plate vii, figs. 1–5) and is very similar to, though considerably lower than, the mountainous region of North-eastern Victoria with which it is continuous. The hilly country follows the outcrop of the schists and later granites and reaches a maximum height in the vicinity of Jindera Gap and north of Lavington where Hamilton and Black Range Trigonometrical Stations rise to 1,540 ft. and 1,556 ft. respectively (Plate vii, figs. 4 and 5, and Plate viii, figs. 7 and 8). This area is drained by the headwaters of Bungambrawatha Creek in steep precipitous gullies, but the main creek is a mature stream where it emerges from the hills near Lavington and crosses the alluvium to join the Murray River in the town of Albury. To the west of this creek the hilly country slopes westwards and gradually becomes lower as the Western Plains are approached. Creeks draining westwards are more mature than those on the east, their valley floors are wider, and though the walls are still steep, they are opening out in such a way as to indicate that, when the western boundary of the schists comes to be mapped, there will be wide embayments of alluvium along these valleys.

On the east, a ridge of low hills, rising to about 1,000 ft., forms the western shore of the Bowna Arm of the Hume Reservoir. At its northern end the rocks are porphyries and rhyolites which pass southwards into quartzites, and north of Thurgona Hill, Ordovician gneisses form a group of hills (Plate vii, fig. 3). Thurgona Hill itself is composed of quartzites injected by granite and exposing masses of gneiss, and the most southern hills on this ridge are composed of granite.

### III. ORDOVICIAN.

#### 1. General Description.

(i). *Schists and Gneisses*.—The schists probably occur in metamorphic zones as they do at Cooma (Joplin, 1942), but until a greater area has been studied no zoning

will be attempted. Good exposures of the least altered schists occur near Jindera Gap and on the Black Range, and although contact-altered by a later granite, the schists near Burrumbuttock are in a comparatively low grade of regional metamorphism.

With the exception of the rocks near Burrumbuttock, which are highly carbonaceous and show affinities to the Coolringdon Beds of Cooma (Joplin, 1942, 1943), the Albury schists bear a close lithological resemblance to the Binjura Beds of Cooma, consisting as they do of aluminous pelites, psammopelites and psammites alternating as distinct beds or as minute seams. As at Cooma, the psammopelite is the most prominent type, but the pelite is locally well developed and is characterized by the development of black ovoid knots varying in size according to locality, from  $\frac{1}{8}$  to 1 inch in length. The type containing the largest knots is particularly well developed on Hamilton Trigonometrical Station. Howitt (1884-1889) makes frequent reference to nodular or knotted schists and Tattam (1929) described the Victorian occurrences of this type as "contact phyllites".

In the town of Albury and along the Howlong Road, the knotted schist is rare and the rocks appear granular, coarser and more micaceous. These features are no doubt due to granitization, caused in part by the proximity of the gneiss and in part by the pegmatite and greisen sills which are so numerous that it is impossible to map them on the scale of the present map.

In the field, three types of gneiss may be recognized, each having certain distinctive macroscopic characteristics. For convenience these will be termed the Albury, Bethanga and Bowna gneisses respectively. Detailed petrographical work may indicate that such a separation is not justified, or that further subdivision is necessary.

Excellent exposures of the Albury gneiss may be seen in the municipal quarry on the Howlong Road at the southern end of Monument Hill. In this quarry pegmatites similar to those forming the acid sills among the schists, are seen cutting the gneiss, and their relative ages may thus be established. The gneiss is a medium-grained plutonic rock with large, scattered composite feldspar units and rounded masses of quartz which may measure up to about  $1\frac{1}{2}$  inches. Foliation is locally developed and the rock is characterized by the presence of numerous sedimentary xenoliths varying from large blocks to minute, almost completely resorbed, fragments. The pelites, banded psammopelites and psammites of the sedimentary series are all represented among the xenoliths, and there is no doubt that the granitic rock has been contaminated as a result of their assimilation. The gneiss contains andalusite and sillimanite in notable amount, and cordierite, though often present, is less common.

The Bethanga gneiss occurs as remnants in a later acid granite near the Hume Weir, and the relations may be studied in the large quarry (Plate viii, fig. 11) from which the material for the construction of the weir was obtained. Small masses also occur along the shore of the Bowna Arm of the Reservoir where they are much weathered and often indistinguishable from the Bowna gneiss. In the field, it appears to be a more basic rock than the Albury gneiss. Foliation is not so well marked, but a coarse gneissic banding is more obvious. The bethanga gneiss is a porphyritic type with numerous orthoclase phenocrysts of variable size. It is crammed with xenoliths in all stages of disintegration and is characterized by the development of large red garnets, nests of which measure over  $\frac{1}{2}$  inch in diameter. In this latter respect it appears to be similar to a rock occurring immediately south of the river at Bethanga in Victoria and termed by Tattam (1929) the "Bethanga Gneiss". For this reason the Victorian name has been applied to the rock occurring in New South Wales. Andalusite and sillimanite are common in the enclosed xenoliths and cordierite occurs in these as well as in the body of the gneiss itself. It is therefore essentially a cordierite-gneiss.

In handspecimen the Bowna gneiss is distinct in being non-porphyritic and in containing a greater abundance of quartz. It occurs along the shore of the Bowna Arm of the Reservoir and north of the old road which crossed the former Hawksview Bridge, south-west of the submerged village of Bowna. The rock is very weathered and it is possible that this gneiss is not a separate type. Gneissic banding is very well marked and excellent examples of *lit-par-lit* injection may be seen along the shore when the reservoir is at a low level. Such structures are best developed on a small peninsula in

Por. 145, Parish of Bowna, which is cut off as a tiny island when the water is at a high level.

(ii). *Granites and Pegmatites*.—Acid granites occupy two areas in the hilly country near Lavington, and these are believed to be of Ordovician age. Where their relation to the Ordovician sediments can be studied they are always concordant, and they are invaded by acid sills similar to those intersecting the schists and Albury gneiss. For convenience these will be termed the Run Boundary and Rocky Hill Sills, though they are possibly of the nature of phacoliths. The outcrop of the Run Boundary Sill measures  $1\frac{1}{2}$  miles by  $\frac{1}{2}$  mile and that of Rocky Hill is  $\frac{3}{4}$  mile in length by  $\frac{3}{8}$  mile in width (see Plate vii, figs. 4 and 5, and Plate viii, figs. 7, 8 and 9). These rocks show some variation within their mass, but all appear to be fairly fine, even-grained two-mica granites locally passing into muscovite-granites. The Rocky Hill granite contains small well-formed garnets. It may have been this granite to which Smith (1894) referred when he spoke of almandine occurring at Albury; for it is possible that specimens of the granite reached the Mines Department in Sydney in connection with the mining activity which was going on in the Black Range area. The Run Boundary Sill contains a slightly more basic granite richer in biotite, and so far garnet has not been detected in it. There are, however, particularly towards the southern margin and western end of the sill, gradations from the biotite-rich type into very acid types.

With increasing acidity these granites appear to grade into a type which forms a series of smaller intrusions lacing the schists (Figs. 1 and 3) and which are intrusive into the granite. These intrusions vary from about 60 feet to a few inches in width, and wherever their relation to the schists can be observed, it is concordant; they are therefore sills. Some of the larger sills, occurring near the town of Albury, have been worked

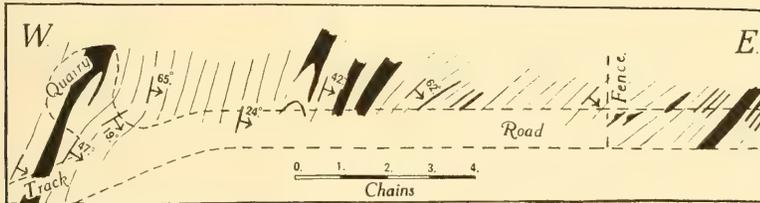


Fig. 1.—Traverse along western end of North Street showing numerous pegmatite sills (black):

for road-material and small quarries can be seen at the western end of North Street (Fig. 1), on the common on the south side of Black Spring Creek, near the saleyards off the old Sydney road and at Doctor's Point. The smaller sills often consist entirely of greisen, of fine graphic pegmatite, of tourmaline pegmatite or of schorl. The larger sills of this group show sudden variations from coarse pegmatite to fine aplite, the two types appearing to grade into one another. In some sills the finer rock occurs at the margin, in others at some distance from the margin. Furthermore, the more acid types such as schorl, etc., often occur in the centre of the larger sills, and it is not usual to find these phases near the margin. It is difficult to say whether such variations are due to differentiation *in situ* or to successive injections. As the very acid material commonly forms the smaller sills, it seems likely that it was injected into the larger sills slightly later, but whilst they were still hot and only partly consolidated. At the head of Bungambrawatha Creek in Por. 134, Parish of Mungabarina, two sets of dykes invade the Run Boundary granite, and in the bed of the creek pegmatite veins may be clearly seen cross-cutting aplites. These small dykes show good examples of displacement.

It would appear, therefore, that there are three groups of sills in the Albury district showing a progressive decline in size and a progressive increase in the acidity of the rock. Thus there are the larger granite sills or phacoliths, the medium sized aplite and pegmatite sills and the narrow sills of pegmatite, schorl and greisen. Plumose mica is a common feature of the acid sills and beautiful examples may be seen near Bungamba Trigonometrical Station and in the little quarries on the common west of the

cemetery. Card (1905) records beryl from a pegmatite on Black Range, and in the mining reports references are made to gold occurring in quartz reefs which appear to be associated with the pegmatites. Although no tin has been found in the Albury sills, they appear to be similar to the stanniferous "dykes" of the Mitta Mitta Region (Whitelaw, Kenny and Easton, 1915) which are stated to have a strike similar to that of the Ordovician sediments and to be usually vertical in dip. This suggests that they may be concordant and, therefore, sills like those of Albury. Tin occurs in New South Wales east and north-east of Albury, but as this area has not yet been examined, no statement can be made regarding its occurrence.

## 2. Structure.

The Ordovician rocks, as shown in Plate vi, are thrown into a series of folds trending W.N.W. There is some indication of their starting as narrow abrupt folds on the west and widening slightly as they pitch towards the east, thus suggesting that they are a series of very narrow, elongated domes or basins. An excellent example of an anticline may be observed on the western side of Jindera Hill, and this appears to widen slightly and to be continuous with the one that determines Jindera Gap. North of the Gap, a syncline may be traced for some distance but in the neighbourhood of Bungambrawatha Creek faulting is suggested by the displacement of these folds. The anticline is extremely asymmetrical and its southern limb flattens out, and although an easterly pitch is obvious, no southerly dips are recorded throughout the hilly country between Jindera Gap and to within a short distance of the Murray River where the other limb of the fold and its southerly dip are recorded (Fig. 2, sections A-B, C-D). Smaller folds trending E.-W. occur in the vicinity of Moorwatha but these have not been traced for long distances.

Many minor puckerings and warps occur across these folds and good examples of these may be seen in the road cuttings near Doctor's Point, along the Howlong Road and in Pemberton Street north of Monument Hill. Where it has been possible to discern the structure, dips on the minor folds have not been taken, so that on the map (Plate vi), with but few exceptions, only dips on the major folds have been recorded.

Howitt (1887) suggested that the metamorphic belt of North-eastern Victoria, of which the Albury schists are the northern extension, is in the form of a major fold, and Tattam (1929) points out that there is a constant S.W. dip which indicates a great overfold or series of smaller overfolds. Obviously much detailed mapping is necessary before this great structure can be clearly interpreted, and the sudden change of dip near Huon Hill north-west of Albury suggests the nose of an anticline pitching north-west. Thus the folds north of Albury would appear to be cross-warps superimposed on a major structure. The W.N.W. trends appear to terminate abruptly near Huon Hill and the north-westerly dip is constant for a distance of at least 10 miles. No doubt Tattam observed many S.W. dips in the course of his field work and has every reason to suggest a great anticlinal structure, but if such exists, the possibility of cross-warping cannot be overlooked. In the far south-eastern end of the region about Omeo and Ensay, Howitt records S.W. and W.S.W. dips, and Easton (1914-1915) shows a series of folds in the Tallangatta area of Victoria which might be a continuation of those warps observed north of Albury. Close folding with similar trends has also been recorded from the Mitta Mitta Tin- and Gold-fields by Whitelaw, Kenny and Easton (1915).

Thus there appears to have been a great elongated dome or anticline pitching to the north-north-west, which may have been overfolded to the west, and upon this has been superimposed a series of intermediate folds or cross-warps which in their turn have been warped into a series of minor buckles.

It has already been pointed out that the displacement of the fold-axes to the west of Black Range suggests a fault, and it is possible that this may have determined the course of Bungambrawatha Creek and that of the old Tertiary River that antedated it (Fig. 3). The age of this possible fault is uncertain, but there is some evidence of a post (?) Lower Devonian fault in the vicinity of Ten Mile Hill on the old Sydney road (Fig. 2, sections E-F, G-H), and it is probable that they are of the same age. Faulting may have been more extensive than is indicated and the depressed area of

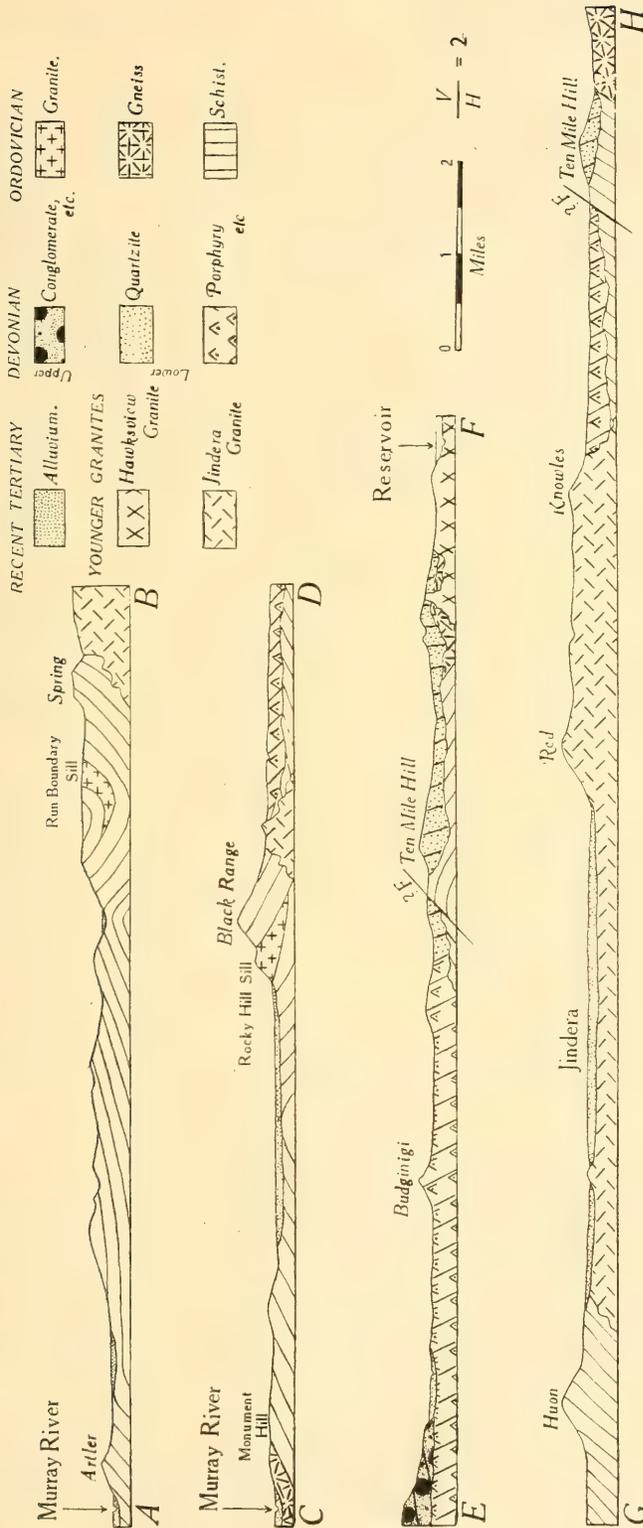


Fig. 2.—Generalized sections across Albany district (see map).

undulating country which is probably occupied by Ordovician schists may represent a downthrown block.

### 3. *The Eastern Area.*

In the Parishes of Thurgona, Bowna and the eastern part of the Parish of Albury it is almost impossible to map owing to the deep soil cover. This area is mainly under cultivation where orchards and vineyards flourish on the deep red soil, which appears to support a different type of vegetation from the river alluvium. This area lies between the 600 ft. and 750 ft. contours and gives rise to gently undulating country in which the creeks have carved deep notches, with soft soil banks and much gullying. An occasional rock outcrop indicates schist or granite but these cannot be followed for distances greater than a few yards, and though such indications suggest that the area is occupied by the Ordovician rocks, only two moderately large outcrops on which it has been possible to measure the dip, have been found within this area. One occurs just north of the racecourse, and the other on the old Sydney road just north of Ten Mile Hill. Boring, however, has established the existence of the schist beneath the alluvium at Lavington (see Fig. 3). On account of the uncertain geology of this area it has been hatched in broken lines to distinguish it from those areas definitely occupied by the Ordovician rocks. The word "outcrop" on the map indicates a definite exposure of schist or pegmatite too small to be indicated by the regular hatching.

It is difficult to explain the reason for such a marked difference in topography between the hilly country definitely occupied by the schists and the subdued undulating country which appears to have been composed of the same material. Obviously the difference cannot be due to differential erosion, and the only explanation appears to be faulting, of which there is some suggestion as indicated above.

As the (?) Lower Devonian porphyries also give rise to deep soil, mainly cultivated, it has been impossible to trace the boundary between the Ordovician and (?) Lower Devonian formations and on the map (Plate vi) many inaccuracies no doubt exist.

### 4. *Age of the Schists and Gneisses.*

Actually in the Albury district no evidence has so far been discovered to give the age of these rocks, but there is no doubt that they are the northern continuation of the Victorian schists which have been definitely proved to be of Ordovician age. In his studies in the extreme south of the metamorphic belt, Howitt (1887) showed that the unaltered rocks could be gradually traced into the highly metamorphosed schists, but at the time, he regarded the unaltered ones as Silurian. These have since been proved to be Upper Ordovician, and Tattam (1929) has been able to trace the progressive metamorphism of graptolite-bearing slates into schists in several areas within the metamorphic belt.

Furthermore, the rocks about Burrumbuttock are highly carbonaceous, a fact suggestive of the Ordovician age, and all the Albury schists show a close lithological resemblance to the Cooma schists of established Ordovician age.

## IV. DEVONIAN.

### 1. (?) *Lower Devonian.*

(1). *Porphyries, Rhyolites and Tuffs.*—There are few outcrops of solid rock in the gently undulating country about Ettamogah and Table Top, but in road- and railway-cuttings a soft white material sometimes occurs, which appears to be deeply weathered porphyry or tuff. Such outcrops are specifically shown on the map and the whole area has been hatched as porphyry. It is not possible to distinguish between tuff and weathered porphyry, and some of the material may be arkose. Soft white material, containing small idiomorphic quartz crystals, and resembling the Table Top outcrops, occurs in the bed of Table Top Creek north of the Hume Highway, and here is overlain by the Upper Devonian sediments.

Budginigi Trigonometrical Station is a small conical hill rising abruptly from the flat surrounding country to a height of 1,035 ft., and on this hill, the rock, though a good deal weathered, is much fresher than elsewhere. It is a definite quartz-felspar-porphyry with somewhat corroded, idiomorphic quartz crystals (about 3 mm. across),

and much sericitized crystals of felspar occurring in a ground mass consisting mainly of sericite and chlorite. Slightly larger flakes of chlorite suggest the former presence of biotite.

The low ridge of hills along the western side of the Bowna Arm of the Reservoir is made up of various rock formations, but the most northerly of these hills consists of fairly fresh porphyry grading into banded rhyolite in Por. 94, Parish of Bowna. At this locality the rocks form a distinct ridge with well-marked outcrops on the steep western side of the hill. In Por. 94 there has been a little quarrying, possibly for road-material for there appears to be no evidence of anything metallic. The dip of the rhyolite banding is E. 20° S. at 68° and though measurements on rhyolitic banding are not regarded as reliable, it compares with the dip of the quartzites occurring further south and into which the porphyries and rhyolites appear to grade.

(ii). *Quartzites*.—As indicated above, there appears to be a gradual passage from porphyry and rhyolite into quartzite in the vicinity of the old Sydney road, Por. 46, Parish of Bowna. Quartzites occur on Ten Mile Hill and on Thurgona Hill, and at this last locality they can be seen overlying gneiss and invaded by a later granite. Owing to the numerous outcrops of these three rocks on Thurgona Hill it was found impossible to map them on the scale of the present map, and the outcrops shown are somewhat diagrammatic to indicate the relations observed in the field.

The quartzites vary from very compact quartzose types to somewhat micaceous varieties. They show a prevailing dip of E. 10°–20° S. Along the travelling stock reserve, south of Pors. 131, 132, 133, Parish of Bowna, there are numerous shafts of old gold mines. The auriferous reefs appear to follow the trend of the quartzites.

## 2. Upper Devonian.

The Yambla Range is capped with Upper Devonian conglomerates, sandstones and shales. These are all of a chocolate or reddish colour and occur in alternating bands ranging in thickness from about 3 in. to 4 ft. Accurate measurements on the dip of the beds have not been made, but it is obvious that the western slope of the cuesta is a gentle dip-slope. A little north-east of Burrumbuttock a group of hills just north of the road and the Gerogery Range further north-east show the same bold outcrops of conglomerate, and here the dip-slopes appear to be easterly. The Upper Devonian sediments thus appear to occur in a wide shallow syncline the axis of which is followed by the railway and Wagga Road.

The conglomerates, though occurring in comparatively narrow beds, are very massive, and single rounded boulders may occupy almost the total thickness of the bed. The boulders are surprisingly unsorted as regards their size, and vary from several feet in diameter to pebbles of less than  $\frac{1}{2}$  inch. They consist almost exclusively of chert and quartz and the matrix is a very hard, compact ferruginous sandstone or grit. The massive conglomerate bands are separated by red sandstones grading into grits and by narrow bands of red shale.

## 3. Age Relations.

There is no direct evidence of the age of any of these rocks that have been put down as Devonian. The red shales regarded as Upper Devonian are identical with those of Mt. Lambie and other well-known Upper Devonian localities and the massive conglomerates are exactly similar to those of the Catombal Ranges near Wellington. There seems to be no doubt that the rocks of the Yambla Range are of Upper Devonian age.

It is pointed out above that this Upper Devonian series overlies the porphyries on Table Top Creek, and if any reliance can be placed on the dip of the rhyolitic banding their relation is unconformable. An unconformity definitely exists between the quartzites and the Upper Devonian strata and between the quartzites and the Ordovician as exhibited in the road-cutting near Ten Mile Hill. The porphyry series and the quartzites are thus pre-Upper Devonian and post-Ordovician, and they may therefore be of Silurian or of Lower or Middle Devonian age. Until further evidence is available it seems desirable to refer the porphyries and rhyolites to the Snowy River Porphyry Series of

Lower Devonian age as outcrops of this series occur only about 30 miles distant in Victoria. At the same time it must be kept in mind that porphyries are very common in the Silurian elsewhere in New South Wales, though they seem to have no lithological resemblances to the Albury rocks. The quartzites obviously overlie and are closely related to the rhyolite and the same age must be assigned to them.

#### V. YOUNGER GRANITES.

Two types of younger granite occur; one a fine even-grained rock occurring on the Hawksview Estate and forming the hills north of Hume Weir, the other a porphyritic granite cropping out over a fairly large area north of Albury and forming the hills west of Table Top. The porphyritic granite also occurs at intervals between Jindera and Burrumbuttock where it has altered the Ordovician schists. This suggests that the smaller outcrops are the unweathered remnants of a much larger mass which extends beneath the Jindera alluvium (see Fig. 2, section G-H). As the relative ages of these granites are uncertain they will be described separately and their ages subsequently discussed.

##### 1. *Hawksview Granite.*

This is a fine-grained light grey two-mica granite and in the Hume Weir Quarry it can be seen to have invaded and engulfed the Ordovician gneiss with which it shows slight hybridization. Gold and arsenic are associated with this granite, and the gold occurring in the quartzites further north appears to be associated with this intrusion.

Under the microscope the rock shows a fairly even grain-size of about 0.5 mm. with rare orthoclase phenocrysts up to 3 mm. The essential minerals are quartz, oligoclase, biotite, muscovite and a little apatite. Xenocrysts of altered andalusite, red biotite containing zircons, and zoisite are sometimes present. Most of the rocks are allotriomorphic granular, but some, richer in plagioclase, are hypidiomorphic granular. Many of the rocks are much greisenized and small greisen veins about 1 inch in width sometimes occur.

##### 2. *Jindera Granite.*

This rock is characterized by the presence of pink oligoclase phenocrysts measuring up to 2 mm. The groundmass has a grain-size of about 0.75 mm. and consists of quartz, orthoclase, biotite and apatite. In handspecimen the relative amounts of these minerals and their state of alteration give a slightly different colour to the groundmass of the rock which varies from light to dark grey and dark greenish-grey.

Dykes of fine even-grained acid granite cut the porphyritic granites on the Wagga Road, near Knowles Hill, and on the northern flank of Black Range. Only two of these have been sectioned, and though appearing rather similar in handspecimen, they are very different under the microscope. Thus the rock from the Wagga Road, though appearing fairly even in handspecimen, contains phenocrysts (2 mm.) of microcline-microperthite in a groundmass (0.5 mm.) of quartz and microcline.

A specimen from Black Range contains quartz, subidiomorphic plagioclase, muscovite, a little chloritized biotite and some zircon, and is thus not unlike certain specimens of the Hawkesview granite.

##### 3. *Age of the Granites.*

There is no direct evidence of the age of either of these granites except that they are younger than the Ordovician schists and gneisses, and as they bear no resemblance to the Ordovician granites they are probably of post-Ordovician age. The porphyritic granites are very similar to granites of Kanimbla age (Late Devonian or Carboniferous—Sussmilch, 1914), elsewhere in the State, but until further microscopic work and chemical work is carried out, it would be unwise to refer them to this epoch. Furthermore, it is likely that field evidence may be available further north in the region of the Upper Devonian rocks.

If a correlation could be made on the slender evidence of a similarity between the Hawksview granite and a single dyke rock cutting the porphyritic granites on the northern flank of Black Range, then the age of the Hawksview granite would be post-

porphyritic granite or possibly late Kanimbla Epoch. This, however, is not regarded as satisfactory evidence, and it seems better to leave the matter as an open question until further detailed petrography is undertaken.

The porphyritic granite appears to be non-auriferous, but both gold and arsenic are associated with the Hawksview mass, and there are gold reefs in the (?) Lower Devonian quartzites to the north, so the Hawksview granite might be regarded as at least post-Lower Devonian. Browne (1929) has pointed out that granitic intrusion is usually, if not always, associated with a diastrophic epoch. Thus there appears to be a possibility of either or both of the younger granites being of Middle Devonian age, since an unconformity exists between the (?) Lower Devonian quartzites and the Upper Devonian sediments. A Middle Devonian diastrophism has been recorded in certain parts of Victoria (Skeats, 1928), and Brown (1932) has pointed out that there is evidence of this movement in certain parts of New South Wales.

#### VI. TERTIARY AND RECENT.

The Murray River alluvium and the alluvium about Jindera, which extends westwards into that of the Western Plains, are possibly of both Tertiary and Recent origin.

During a search for alluvial gold in 1900, experimental boring proved the existence of two Tertiary leads near Lavington. Forty-five bores were put down along a line extending east from Lavington Post Office to within 20 chains of the Wagga Road. One lead was found immediately west of Por. 617, Parish of Albury, and possibly running just west of the present course of Bungambrawatha Creek, and the other in Por. 486, Parish of Albury, and possibly running south-east towards the racecourse and entering the Murray River near Mungabarina Lagoon. Whittell (1901) has published a section across these leads which is reproduced, with slight modification, in Fig. 3. The maximum depth of the leads is 315 ft. and the material filling them consists of micaceous clay,

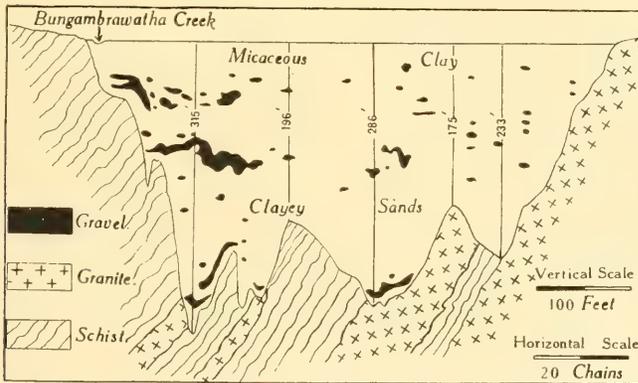


Fig. 3.—Modified reproduction of section across Tertiary leads near Lavington. (A. R. Dept. Mines, N.S.W., for the Year 1900).

clayey sand and occasional patches of gravel. Gravels at the base of the leads proved to be auriferous, but they have never been opened up owing to the high cost of working. It has been suggested (Pittman, 1899) that a lead, possibly representing an old channel of the Murray River, passes between Doctor's Point and Huon Hill, but this has not been proved.

Elsewhere it has been pointed out that the Ordovician rocks usually rise rather abruptly from the flat alluvial country, but in places particularly about the Hamilton Valley and Jindera, mapping has been difficult owing to colluvial soil which forms a slight terrace above the flat alluvium and shows no outcrops of solid rock.

The alluvium about Jindera is a very fine-grained clayey material, often containing calcareous nodules up to 3 inches across and of somewhat irregular shape.

Pisolitic soils occur in many parts of the area, particularly to the east over the undulating country which is believed to be deeply weathered schist. In a road-cutting

south of the Roman Catholic Orphanage, Pors. 118/114/113, Parish of Albury, about 1 foot of very rotten granite is exposed, passing up into a pisolitic B-horizon 4 feet thick, which is overlain by about 3 feet of red soil. Between Ettamogah and the old Sydney road, near Thurgoona, pisolitic gravel occurs on many parts of the surface. The underlying rocks are probably both schists and (?) Lower Devonian porphyries.

#### VII. SUMMARY.

An area of approximately 300 square miles has been examined in the Albury district. Within this area Ordovician and Devonian rocks are developed. The Ordovician series consists of schists, traversed by pegmatite sills, two granite phacoliths and several highly contaminated orthogneisses. To the north, these are unconformably overlain by (?) Lower Devonian porphyries, rhyolites, tuffs and quartzites, and still further north, the porphyries are overlain, apparently unconformably, by Upper Devonian sediments. Two types of younger granite occur, and it is suggested that they might be assigned either to the Middle Devonian or to the Kanimbla Epoch. Tertiary and Recent alluvium and soils are briefly described and short comments are made on the physiography.

#### VIII. Acknowledgments.

In conclusion, I wish to thank Miss F. M. Quodling, B.Sc., for information generously supplied by her after a reconnaissance visit to Albury. I am much indebted to Dr. W. R. Browne for his ready assistance, for his critical reading of the manuscript of this paper and for the photograph of the Murray Valley (Plate vii, fig. 1). For the other photographs (Plates vii and viii) I am indebted to Miss M. J. Colditz, B.Sc., to whom I tender my grateful thanks.

For help during field work I wish especially to thank Miss I. Maclean and Mr. A. Conness of Table Top and Mr. and Mrs. C. Rapsey of Hume Weir.

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#### EXPLANATION OF PLATES VII-VIII.

##### Plate vii.

Fig. 1.—Looking up Murray Valley from south end of Monument Hill. Note winding course of river and wide area of river alluvium. South Albury is shown in the middle distance. The hill on the right, east of Albury, is composed of schist and is in New South Wales. The other hills are in Victoria. Photograph by W. R. Browne.

Fig. 2.—Flat alluvial country about Jindera showing Ordovician hills in the distance. Huon Hill on right with Jindera to left of it.

Fig. 3.—Undulating country about Thurgona looking east towards hills bordering Bowna Arm of Reservoir. Hills to left are gneiss and the rest quartzite. The far distant and more elevated country is in Victoria.

Fig. 4.—Undulating country near Thurgona looking west towards hills. Hills from left to right are Hamilton (schist), Rocky Hill (granite sill), Black Range (schist), Spring (schist), Red (younger granite), Knowles (younger granite). Note cultivation of undulating country.

Fig. 5.—Rocky Hill and Black Range from Thurgoona Road looking across undulating country. Note orchard.

(Photographs 2-5 by M. J. Colditz.)

Plate viii.

Fig. 6.—Hilly country of Ordovician schists looking down valley towards Hamilton Valley and Lavington from north of Jindera Gap.

Fig. 7.—Hilly country from Run Boundary Sill looking east towards Black Range and Rocky Hill.

Fig. 8.—Hilly country from Run Boundary Sill looking south towards Hamilton.

Fig. 9.—From Run Boundary Sill looking north towards Red (younger granite) and more distant Yambla Range (Upper Devonian sediments). Note westerly dip-slopes of Yambla Range.

Fig. 10.—Hume Reservoir from near Bethanga Bridge looking west towards weir. Distant hills are in Victoria. The foreground is composed of younger granite.

Fig. 11.—Weir Quarry in younger granite. Though not intended for a panorama, Figs. 10 and 11 may be looked at together, and except for a small hiatus which cuts out the road, the view is almost continuous.

(Photographs by M. J. Colditz.)

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PRODUCTION OF NITRATE FROM ROOTS AND ROOT NODULES OF LUCERNE  
AND SUBTERRANEAN CLOVER.

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(One Text-figure.)

[Read 25th October, 1944.]

*Introduction.*

Trumble and Shapter (1937) showed that when grass (*Phalaris tuberosa*) was grown in almost nitrogen-free sand together with annual legumes (*Medicago denticulata* or *Trifolium subterraneum*) there was no evidence of any transfer of fixed nitrogen from the legume to the grass during active growth of both plants, but that the growth of the grass was rapidly stimulated after removal of the tops of the legumes. The authors ascribed this phenomenon to release of available nitrogen from the decaying root systems of the legumes; their data, however, show that only a moderate proportion (30 per cent., or less) of the total nitrogen contained in the legume root systems had been taken up by the grass. An important factor governing the utilization of this nitrogen is, obviously, the rate at which the organic constituents of the roots and nodules are decomposed and their nitrogen converted into ammonia and nitrate; at the same time the possibility exists that soluble organic nitrogenous compounds may be utilized by the grass before they reach the inorganic stage (Nicol, 1934); such compounds might represent either native constituents of the legume tissues, or products of the microbial decomposition processes. Since the root nodules differ considerably from the rest of the root tissues in chemical composition (Fred *et al.*, 1932), it is likely that they also differ in the availability of their nitrogen. Experiments on legumes as green manure to non-leguminous plants are almost innumerable, and several authors, e.g., Whiting (1926), Whiting and Richmond (1927), and others quoted by Fred *et al.* (1932), have studied the comparative rates of nitrification of tops and roots of different legumes, but in none of these contributions is any distinction made between the nodules and the actual roots. We have therefore carried out some such experiments with materials representing two important pasture legumes, viz., lucerne (*Medicago sativa*) and subterranean clover (*Trifolium subterraneum*), at an age comparable to the plants in the experiments of Trumble and Shapter (1937).

EXPERIMENTAL.

*Methods.*—The plants that yielded the materials were grown for 3 to 4 months under greenhouse conditions in sand very poor in nitrogen, some of them also in soil of fairly low humus content, and all inoculated with effective strains of the corresponding root-nodule bacteria. Materials from different experimental series had to be combined in order to get a sufficient supply of nodule substance. Table 1 shows the contents of carbon and total and water-soluble nitrogen in the plant substances as used for the subsequent experiments (finely ground, air-dry material). Carbon was determined by elementary analysis, and nitrogen by the Kjeldahl method, with selenium as a catalyst. Water-soluble nitrogen was determined by shaking 1 gm. of material, or 0.2 gm. in case of nodule substance, with 100 ml. of distilled water for 3 hours in a mechanical shaker, filtering, washing with distilled water until 200 ml. of filtrate had been collected, and analyzing the total filtrate for nitrogen. Ammonia and nitrate were determined by the method of Richardson (1938).

TABLE 1.  
*Composition of Plant Materials.*

Material.	In Air-dry Matter, %.		C : N Ratio.	Water-soluble N, %.	
	Total C.	Total N.		In Air-dry Matter.	Of Total N.
Lucerne tops .. ..	39.4	2.48	16.0	0.712	28.7
"  roots .. ..	40.7	1.58	25.8	0.630	39.8
"  nodules .. ..	40.5	5.94	6.8	— <sup>1</sup>	—
Clover tops .. ..	40.7	2.63	15.5	0.270	10.2
"  roots .. ..	37.6	2.20	17.1	0.364	16.7
"  nodules .. ..	47.3	7.42	6.4	2.210	29.8

<sup>1</sup> Insufficient material available for the determination.

*Rate of Nitrification.*—The nitrifiability of nitrogen in all six materials was tested in a mixture of sand and loam soil, of pH 7.2 and very low nitrogen content (0.019% Total-N), to which the materials were added in quantities equivalent to 50 p.p.m. of nitrogen. Duplicate portions of soil were adjusted to approximately 12% moisture content and incubated at 30°C. in glass jars covered with Petri dishes; losses of moisture were restored every two or three days by addition of distilled water, and ammonia and nitrate were determined after 2, 5 and 8 weeks. No measurable quantities of ammonia were found; therefore only the figures for nitrate are given in Table 2; the percentage nitrification of nitrogen in the added plant substances is calculated as excess over the average of the two control jars.

TABLE 2.  
*Production of Nitrate from Leguminous Plant Materials.*

		NO <sub>3</sub> -N, p.p.m., after			Percentage of added N Nitrified after	
		14 Days.	35 Days.	56 Days.	14 Days.	35 Days.
Lucerne tops.	(a) .. ..	6.6	28.8	28.4	10.4	53.0
	(b) .. ..	7.6	27.0	29.1	12.4	49.4
"  roots.	(a) .. ..	2.2	19.1	20.5	1.6	33.6
	(b) .. ..	1.3	17.9	19.4	(0)	31.2
"  nodules.	(a) .. ..	14.9	46.2	30.4	27.0	87.8
	(b) .. ..	15.1	46.7	34.4	27.4	88.8
Clover tops.	(a) .. ..	9.4	26.5	33.8	16.0	48.4
	(b) .. ..	7.7	25.9	29.6	12.6	47.2
"  roots.	(a) .. ..	8.5	21.0	33.2	14.2	37.4
	(b) .. ..	7.7	24.9	29.4	12.6	45.2
"  nodules.	(a) .. ..	12.7	47.2	23.4	22.6	89.8
	(b) .. ..	12.7	45.4	33.0	22.6	86.2
Control.	(a) .. ..	1.8	2.7	16.9	—	—
	(b) .. ..	1.0	1.9	14.4	—	—

After 2 and 5 weeks, the two nodule materials show the most rapid nitrification, which reaches almost 90%, and the lucerne roots the slowest, while the tops and the clover roots occupy intermediate positions. After 8 weeks, the results become inconclusive, because a marked loss of nitrate has taken place in the jars with nodule substance, and the control jars show a sudden increase in nitrate which makes it difficult to gauge the nitrification of the other materials; it is by no means certain that an equally strong production of nitrate from the soil's own organic matter would have taken place in the presence of added organic matter. Yet the rather small increase in nitrate content between the fifth and eighth week suggests that the nitrification of the residual nitrogen in tops and roots now takes place at only a slow rate.

After 2 and 5 weeks, there is a close negative correlation between nitrification and C:N ratio of the materials. By calculating the correlation coefficients between C:N ratio and percentage nitrification for the two sets of duplicate jars, and combining them into one by calculating the corresponding values of  $z$  (Fisher, 1936), we find:

	Correlation Coefficient ( $r$ ).	n	P
After 2 weeks .. .. .	-0.810	6	0.02-0.01 (significant)
„ 5 „ .. .. .	-0.789	6	0.02-0.01 „

Several authors, e.g., Whiting and Richmond (1927) have reported a positive correlation between the rate of nitrification and the amount of water-soluble nitrogen in the materials. Our data give no indication of this; indeed, the nitrogen in lucerne roots is nitrified most slowly of all, in spite of the fact that this material contains more soluble nitrogen than any other, and the nitrogen in clover tops is nitrified as rapidly as that in lucerne tops which are nearly three times as rich in soluble nitrogen.

*Vegetation Experiments.*—Direct utilization of nitrogen in some of the materials (clover nodules, and clover and lucerne roots) by wheat plants was tested in a supplementary experiment. Quantities equivalent to 40 p.p.m. of nitrogen were added to duplicate 600-gm. portions of sand mixed with 20% of the same soil as used in the nitrification experiments, and 0.3 gm. CaHPO<sub>4</sub>, 0.06 gm. KCl and 0.06 gm. MgSO<sub>4</sub> were added as mineral fertilizers. The sand medium was placed in the same jars as previously used, 15% of water was added, and four grains of wheat (“Warigo”) were sown per jar; after germination the seedlings were thinned to two per jar. The plants were grown for eight weeks (17th April to 13th June, 1944) under greenhouse conditions, and were then analysed for nitrogen *in toto* (tops and roots carefully washed free from sand). After removal of the plants the sand-medium was air-dried, readjusted to 10% moisture, returned to the jars, and incubated for 4 weeks at 30°C. in order to test the availability of the nitrogen that had not been taken up by the plants. No ammonia, and only traces of nitrate, were shown by qualitative tests immediately after harvesting of the plants. The contents of nitrogen in the wheat plants and the subsequent formation of nitrate is shown in Table 3; as in the previous nitrification experiment, no accumulation of ammonia took place.

TABLE 3.  
*Assimilation by Wheat Plants, and Subsequent Nitrification, of Nitrogen in Roots and Root Nodules.*

Source of Nitrogen.	N in Plants, Mgm.		NO <sub>3</sub> -N Produced, P.p.m.		Percentage of added N made Available.			
	Total.	Excess over Control.	Total.	Excess over Control.	Assimilated by Plants.	Nitrified.	Total.	
Clover nodules.	(a)	13.3	9.2	7.3	3.4	38.3	8.3	46.8
	(b)	13.6	9.5	6.8	2.9	39.6	7.3	46.9
„ roots.	(a) ..	8.0	3.9	4.3	0.4	16.4	1.0	17.4
	(b) ..	7.8	3.7	4.1	(0.2)	15.4	(0.5)	15.9
Lucerne roots.	(a)	5.6	1.5	5.5	1.6	6.3	4.0	10.3
	(b)	5.8	1.7	4.8	0.9	7.1	2.3	9.4
Control.	(a)	.. 3.9	} 4.1	3.7	} 3.9			
	(b)	.. 4.3		4.1				

The analysis of the wheat plants, as well as their appearance at the time of harvesting (Fig. 1), shows a definite superiority of the nodule-nitrogen, of which nearly 40% has been utilized, while clover-root nitrogen is less than half as effective, and the availability of lucerne-root nitrogen is barely measurable; this agrees with the results of Parbery and Swaby (1942), who found that only such materials which contained at least 2.0 to 2.5% nitrogen in dry matter gave any benefit to rye grass in pot experiments. Very little available nitrogen was provided by the medium itself, as shown by the fact that



Fig. 1.—Wheat plants with different sources of nitrogen. From left to right: Control (no N); 24 mgm. N as lucerne roots; do. as clover roots; do. as clover nodules. Age of plants: 8 weeks.

the control plants contained only two to three times as much nitrogen as originally present in the seed which contained 1.52 mgm. N per two grains. Also in the subsequent nitrification test, the residual nitrogen of the nodules undergoes some nitrification, while that in the two root materials is only very slowly transformed; especially the clover-root substance seems to have yielded all its readily available nitrogen to the wheat plants.

#### DISCUSSION.

The results show clearly that the nitrogen in root nodules is much more rapidly transformed into plant food than that in the rest of the root system. As seen by comparison with data given by Fred *et al.* (1932) and Wilson and Westgate (1943), the nodule substances used in the present experiments show a high, although not exceptional, percentage of nitrogen, so that presumably their C:N ratios would be narrower, and the nitrifiability higher, than would be the case with most nodule materials. But since nodule material is mostly, and probably always, richer in nitrogen than the corresponding root material, we may expect the general rule to apply that dead root nodules represent a source of nitrogen which readily becomes available to non-leguminous plants, while the root substance proper yields up its nitrogen more gradually, probably owing to its relatively higher content of organic carbon which serves as energy material for micro-organisms temporarily immobilizing some of the nitrogen. In the experiments of Trumble and Shapter (1937), the nitrogen responsible for the improved growth of grass after cutting the tops of associated legumes, thus probably originated from the root nodules rather than from the roots themselves. On the other hand, the long-term effect of legumes in increasing the yield of subsequent cereal crops (Nicol, 1933) may be ascribed largely to the more slowly mobilizable nitrogen of the root substance proper. The superiority of lucerne in this respect, as observed by Nicol, may be due to the fact that lucerne contains a larger proportion of root-nitrogen than the annual legumes. This, as well as the fact that a considerable proportion of the plants' total nitrogen content is represented by the nodule substance, may be seen from the following data which show the distribution of nitrogen in the plants from which the materials used in our experiments were derived, besides a few others also grown for 3 to 4 months in sand or in soil of low humus content:

	Percentage of Plants' Total Nitrogen in		
	Tops.	Roots.	Nodules.
<i>Medicago sativa</i> .. .. .	50-66	29-43	4.5-12.5
<i>Medicago tribuloides</i> .. .. .	80-82	13-15	3.4-7.2
<i>Trifolium subterraneum</i> .. .. .	69-85	11-21	3.6-12.6
<i>Trifolium repens</i> .. .. .	81-84	11-14	3.5-4.4

Obviously even a partial release of the nitrogen in the nodules might result in a perceptible stimulation of associated non-legumes. Such a release might take place not only from entire root systems left behind by dead leguminous plants, but also from nodules lost during active growth. As shown by Wilson (1931, 1942), clipping of the tops as well as intermittent drought causes shedding of a certain proportion of the nodules, the nitrogen of which will thus be rendered available. This phenomenon may not only be of importance under field conditions, but may also exist in pot experiments, and represents one of the many factors to be taken into consideration in experimental work on the excretion of nitrogenous compounds from the root systems of leguminous plants.

#### SUMMARY.

The nitrogen in root nodules of lucerne and subterranean clover was nitrified more rapidly than that in the tops, and this again more rapidly than the nitrogen in the root tissues proper. Nearly 90 per cent. of the nodule-nitrogen could be converted into nitrate within 5 weeks at 30°C. The rate of nitrification showed a significant negative correlation with the C:N ratio of the substances, but showed no correlation with the content of water-soluble nitrogen. Experiments on the availability of root- and nodule-nitrogen to young wheat plants gave results in agreement with the nitrification tests. The nitrogen of dead root nodules thus seems readily to become available to non-leguminous plants, while the root substance itself represents a more slowly mobilizable reserve of nitrogen.

#### Acknowledgements.

We wish to thank Mrs. Daphne M. Buckley, B.Sc., Department of Organic Chemistry, for the carbon determinations, and Mr. S. Woodward-Smith, Department of Medical Artistry, for the photograph.

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## NOTES ON AUSTRALIAN MOSQUITOES (DIPTERA, CULICIDAE).

PART V. THE GENUS *ARMIGERES* AND NEW SPECIES OF *ARMIGERES*, *THEOBALDIA* AND *CULEX*.\*

By D. J. LEE, B.Sc.

(Twenty-two Text-figures.)

[Read 29th November, 1944.]

THE AUSTRALASIAN MEMBERS OF THE GENUS *ARMIGERES*.

Species of the genus *Armigeres* found in the Australasian Region have long been subject to misidentification. Recent collections from New Guinea have assisted in bringing clarity to the problems involved, but even so, some points still remain in question concerning the species to be found east and west of New Guinea. It is hoped, however, that publication of present findings may stimulate interest in supplying the obvious lacunae.

At various times the following species of *Armigeres* have been recorded from New Guinea or islands eastwards: *A. obturbans* (Walk.); *A. obturbans* (Walk.) var.? (Edwards, 1924); *A. lacuum* Edw., *A. malayi* Theo., *A. breinli* (Tayl.) and *A. denbesteni* Brug. Of these, however, only the records of *A. lacuum*, *A. breinli* and *A. obturbans* var.? are adequately substantiated, and of these the last constitutes a new species which is herein described. *A. denbesteni* and *A. malayi* are both recorded as occurring on New Guinea by Bonne-Wepster (1938, p. 207) but specific localities are not given. It may reasonably be assumed that the inclusion of *A. malayi* in this author's list of New Guinea species is merely a repetition of an older error and, if *A. denbesteni* is validly included, that it has only been found in Dutch New Guinea.†

The genus is not known to occur on the Australian mainland and it would be of considerable interest to establish the eastern limits of its distribution on islands of the Pacific. As far as information available to me discloses, the genus occurs eastward to the Solomon Islands.

*ARMIGERES MILNENSIS*, n. sp.

I have examined the genitalia preparation referred to by Edwards (1924, p. 368) under *Armigeres obturbans* (Walk.) var.? and found it identical with that of the species described below, which also came from the same locality.

*Types*: Holotype male, allotype female, one male and six female paratypes together with a series of morphotype larvae, all a bred series from Milne Bay collected by D. A. C. Cameron. These have been lodged in the Museum of the Division of Economic Entomology, Council for Scientific and Industrial Research, Canberra, A.C.T.

## DESCRIPTION.

*Male*.

*Head*. The head is bordered with flat pale scales around the eyes, broadening to distinct patches laterally. These pale scales surround a dark-scaled central area, but a few pale scales are also present on either side of the median dorsal line. The clypeus is dark brown; the palpi are longer than the proboscis, and both are clothed with dark scales. The pedicels of the antennae are clothed with loosely applied flat pale scales; the flagella are normally plumose and the last two segments are very considerably elongated.

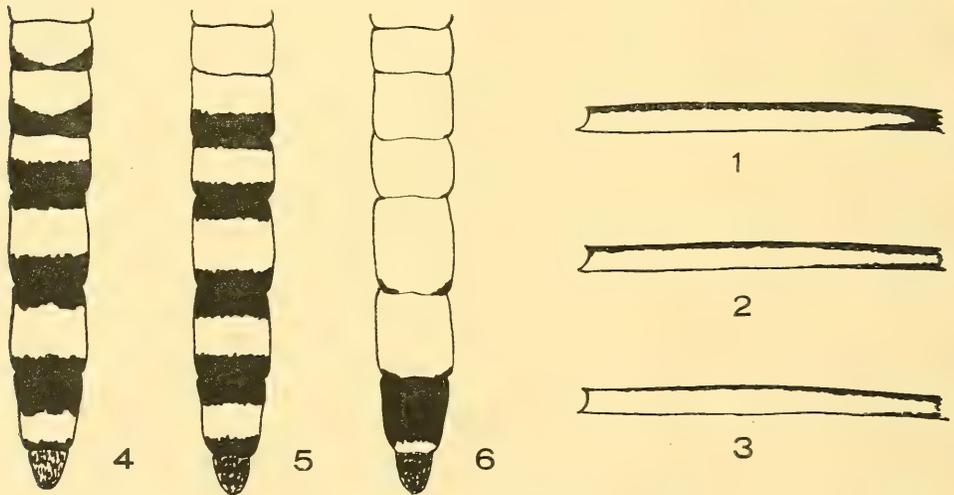
\* Continued from these PROCEEDINGS, lxii, 1937, 294.

† *A. spathulatus* Brug (1939, p. 101) has recently been described from Ceram, but there is nothing in the description to indicate that it is really distinct from *A. denbesteni*, except that there are no lateral pale patches on the head. As the description is from a single reared male specimen, it would be unwise to consider such a difference as of value without further corroborative evidence. Furthermore, the remarks comparing this species with *A. obturbans*, included in the description, do not tally with the description of *A. obturbans* given by Bonne-Wepster and Brug (1937, pp. 15-17). So, lacking an adequate description of the type (which was placed in the British Museum), I considered it unwise to attempt to include it in the key to species.

*Thorax.* Dorsally the scutum is very dark brown and clothed with bronzy, dark brown, narrow curved scales, but there is a narrow line of pale scales along the anterior margin broadening to a distinct silvery lateral stripe which extends to the level of the base of the wing. There are also some pale scales in the triangular area before the base of the scutellum, and also centrally and laterally on the scutellum itself. No central or dorso-central bristles are obvious on the scutum, giving it a rather sleek appearance. Laterally the pronotal lobes and the posterior pronotum are clothed with rather loose white scales, whereas there are closely applied dense white scales over much of the sternopleuron, mesepimeron and postspiracular areas. Spiracular bristles are absent but postspiraculars are present. The propleuron is largely pale-scaled and also bears a group of pale brown bristles. The postnotum is brown and bare, and the halteres comprise a pale stem and dark knob.

*Legs.* The coxae of all legs have distinct patches of pale scales anteriorly. The femora of all legs are dark-scaled above and pale beneath. Those of the hind-legs are pale from the base on the outer lateral surface nearly to the apex (see Fig. 1). The apex is, however, always dark-scaled. The tibiae and tarsi of all legs are entirely dark-scaled. The legs are spinose and this is particularly noticeable on the tibiae and first tarsi.

*Wings.* The costa, sub-costa and radius are clothed with broad, dark scales; the scaling of the rest of the wing veins is also dark but less obvious; the base of the upper fork cell is nearer the apex of the wing than the base of the lower fork cell.



Figs. 1-6.—Outer surface of hind femora and venter of abdomen of various species of *Armigeres*. 1 and 4. *A. milnensis*. 2 and 5. *A. breinli*. 3 and 6. *A. lacuum*. Figs. 1-3,  $\times 14$ , and 4-6  $\times 17$ .

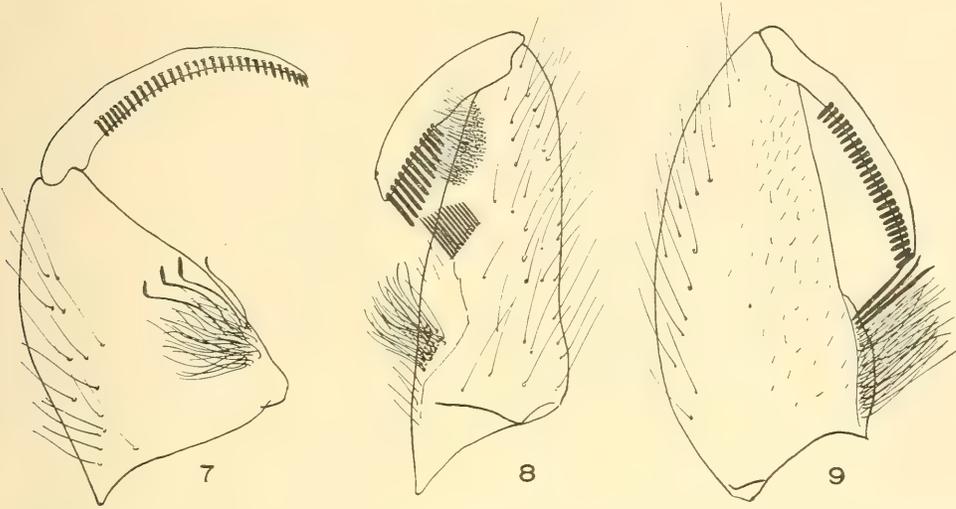
The anterior and middle cross-veins are in a line and distal to the posterior cross-vein. The alula has a fringe of dark scales and the squame is fringed with hairs.

*Abdomen.* As in related species, the abdomen is clothed dorsally with closely applied overlapping broad dark scales which are iridescent in some lights and give a distinct velvety appearance. Segment VIII has a patch of white scales basally on the dorsum.

The tergites have rather triangular, lateral patches of pale scales on all segments but these are seldom visible dorsally. The venter (Fig. 4) has segment I pale; segment II is largely pale-scaled, but with an irregular scattering of dark scales, particularly distally. Segment III is pale-scaled basally, dark distally, and segment IV is similar; segments V, VI and VII are dark both basally and apically with a central pale band; segment VIII is largely pale basally and dark along the distal margin.

*Genitalia* (Fig. 7). The coxites are tapering; the basal lobes are clothed with long hairs which are slightly thickened, and the most distal three or four are more strongly

developed, and both curved and clubbed. The style bears a long row of equal teeth, from 27 to 30 in number, extending from the apex almost to the base of the style. There is no comb present on the distal portion of the coxite.



Figs. 7-9.—Coxite and style of various species of *Armigeres*, all  $\times 126$ . 7. *A. milnensis*. 8. *A. breinli*. 9. *A. lacuum*.

#### Female.

Apart from sexual differences, the female is essentially similar to the male. The palpi are scarcely a quarter the length of the proboscis and dark-scaled. There are usually no more than two or three pale scales on the central dark area of the head and these are quite irregular. The pale scaling on the scutellum is also irregular and may be absent. The basal pale band dorsally on segment VIII of the abdomen covers the greater part of the tergite.

#### Larva.

The larvae of this species conform in general details to other members of the genus. The head (Fig. 10) is round, with short, stout antennae; the antennal shaft hair is very minute and situated at about the middle of the antenna; head hair A is bifid or trifid, B is simple, and C has one to four branches; hairs A, C and f are very finely frayed.

The lateral comb of the eighth segment consists of ten or eleven fringed scales (Fig. 12). The first pentad hair is minute and multi-branched; the second is also minute with three or more fine branches, the third is strong and obvious, with five or six plumose branches, and the fifth is strong and simple.

The siphon is short and stout with a minute three- or four-branched dorso-lateral hair. No ventro-lateral tufts or pecten are present. The saddle of the anal segment scarcely covers the dorsal half of the segment. There is a minute branched saddle hair and the anal papillae are very large, between three and four times the length of the anal segment and sausage-shaped. There are five minutely plumose hairs in the dorsal sub-caudal tuft and three similar hairs in the ventral sub-caudal tuft. No grid is present and the hairs of the ventral brush are also minutely plumose. The terminal segments are illustrated in Fig. 11.

*Distribution*.—Apart from the type locality (Milne Bay) where this species is common, specimens have been examined from Lae, Lalapipi, Bulldog, the Mekeo district and the Lakekamu Goldfield.

#### ARMIGERES BREINLI (Taylor).

*Armigeres breinli* (Tayl.) 1914, *Trans. Ent. Soc. Lond.*, 1914, 186 (as *Neosquamomyia breinli*).

*Types:* As the female was described first, the type of this sex may be considered the holotype. The specimen is No. 235 in the Collection of the School of Public Health and Tropical Medicine, University of Sydney. The specimen designated as type male (No. 234) is not conspecific with the female type nor does it conform to the original description of the male. The genitalia are absent from this specimen and it is obviously the one referred to by Edwards (see note below). Furthermore, there are no scales on the clypeus and the white line on the outer side of the hind femora does not extend to the apex. It is, then, a specimen of *A. milnensis*, n. sp. described above. As no real allotype exists for *A. breinli*, I have designated a specimen from Milne Bay as such and lodged it in the C.S.I.R. Museum, Canberra, A.C.T., together with a series of both sexes and associated larvae which have formed part of the material on which this revision is based.

*Note:* Edwards (1924, p. 368) mentions that he has examined a slide prepared by Hill, allegedly from the type male of *A. breinli*, but that it was obviously not the one described by Taylor. This slide still exists labelled as type male of *A. breinli* in the Slide Collection of the Council for Scientific and Industrial Research, Division of Economic Entomology, Canberra, A.C.T. It is the one referred to above under *A. milnensis*.

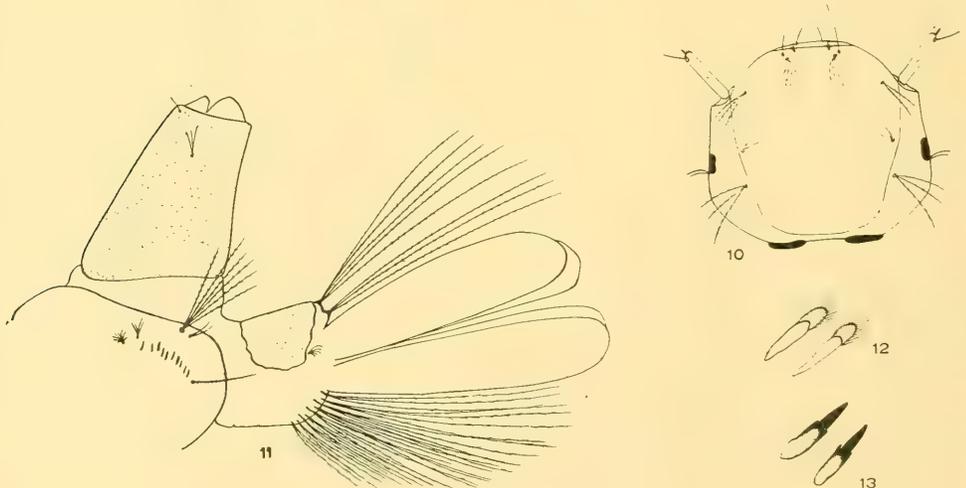
*Type Locality:* Not expressly stated in original description, but that of the type female was Milne Bay and that of the type male originally designated, Lakekamu Goldfield. The allotype male designated by me is topotypical with the holotype female.

#### DESCRIPTION.

Taylor's original description of this species is adequate except that it should be noted that the hind femora are white to the apex of the outer side (Fig. 2) and segment VII of the female abdomen is pale basally (not apically). In the male as well, a few pale scales may at times be seen basally, if the abdomen is extended. Frequently a very few pale scales may be scattered irregularly on the dorsum of segment VI. The venter has the first two segments pale-scaled, segment III with a broad apical dark band, IV, V, VI and VII with narrow basal dark band, broad central pale band and apical dark band, and VIII is rather indefinitely mottled or dark (see Fig. 8).

#### Male.

The characters mentioned above apply equally to the male. The genitalia (Fig. 8) have the basal lobe invested with long hairs. At about the middle of the coxite is a



Figs. 10-13.—Larval characters of *Armigeres*. 10, Dorsal view of head of *A. milnensis*,  $\times 26$ . 11, Terminal segments of *A. milnensis*,  $\times 26$ . 12, Lateral comb scales of *A. milnensis*,  $\times 185$ . 13, Lateral comb scales of *A. breinli*,  $\times 185$ .

row of stout spines resembling a comb comprising about twelve teeth. The style has a tapering row of teeth the apical one being longest; about nine are present in all.

#### Larva.

The larva of this species is very similar to that of *A. milnensis* but may be distinguished on certain characters of the terminal segments. In particular, the lateral comb (Fig. 13) comprises about nine pointed teeth, which may bear a few minute spines at the base of the main central tooth, but they are never fringed; there are also fewer hairs in the third pentad hair, usually three or four.

This species obviously comes very close to *A. malayi*, but may be distinguished in both sexes by the venter (in *A. malayi* this is entirely white on segments I-VII), and in the male the spines on the style taper more evenly (in *A. malayi* the apical tooth is very much longer than the preceding one and there are more teeth; about sixteen).

*Distribution*.—Originally described from Milne Bay. Specimens have been examined from Milne Bay, Lae, Dobadura and Oro Bay. It is also recorded from Fak-fak, Dutch New Guinea (Brug, 1934, p. 514).

#### ARMIGERES LACUUM Edwards.

Edwards, F. W., 1922, *Bull. ent. Res.*, xiii, 97.

*Types*: Type male deposited in Budapest Museum. (Paratypes were deposited in the same museum and in the British Museum, but it will be shown below that these are unlikely to be conspecific.

*Type Locality*: Ile des Lacs (East of New Guinea). Nowadays this island is known as Garove, one of the Vitu Islands.

*Material Examined*: I have based my conception of this species on a series of specimens collected by G. F. Hill from New Britain. These specimens were determined as *A. lacuum* by Edwards and returned to Hill. They are part of the material referred to by Edwards (1923, p. 6).

#### DESCRIPTION.

##### Female.

The characters which serve to distinguish this species are as follows: The clypeus is without scales, the venter (Fig. 6) is almost entirely white with the exception of sternite VII, and the hind femur is white, on the outer lateral surface, to the apex (Fig. 3).

##### Male.

The male agrees in the above characters. The genitalia (Fig. 9) are distinctive in having the basal lobe of the coxite covered with long fine hairs, the most distal three to five of these being thickened. The style bears 20-21 teeth on about the distal three-quarters.

##### Larva.

The larva of this species has been figured by Hill (1925, Plate vi, fig. 12), but the details given are inadequate to differentiate the species from *A. milnensis* in the larval stage. The lateral comb teeth are fringed so that the species may be distinguished from either *A. breinli* or *A. malayi*. In Hill's figure a strong branched hair is shown anteriorly to the lateral comb. Such a hair is to be found in all fourth stage larvae of species of this genus and is the developing pupal hair found at the postero-lateral corner of the eighth segment. This hair will not, of course, be found in cast skins.

*Distribution*.—*A. lacuum* was first found on Garove and has since been recorded from New Britain (Toma, Beining district and Rabaul). It has not been found on New Guinea.

*Note*: In Edward's original description he notes that it is possible that the males and female of the type series may not be conspecific. The male is the holotype and should be taken as the basis of this species. Some, if not all, of the female paratypes, are obviously a distinct species since, in contrast to the holotype, there are patches of scales on the clypeus, a character which, on available evidence, must be considered distinctly valuable. Re-examination of the type series is necessary before it can be

decided whether this other species is *A. breinli*, *A. malayi* or an undescribed species. The only evidence available to me comes from a pair of female specimens collected by Dr. G. A. M. Heydon on Bougainville. These have the clypeus scaled, the hind femora white on the outer surface right to the apex, and the venter is almost entirely pale-scaled but has very narrow apical dark bands on sternites IV-VII. These are somewhat broader laterally and on the anterior segment (II and III) only the lateral patches of dark scales are present on the sternites. *Armigeres lacuum* of Bonne-Wepster and Brug (1937, p. 19) is a case of mistaken identification as their description and figures in no way apply to *A. lacuum* as described by Edwards (male only) or as interpreted above for both sexes.

#### ARMIGERES DENBESTENI Brug.

Brug, S. L., 1925, *Bull. ent. Res.*, xv, 345-7.

*Types*: Holotype male and paratypes of both sexes, and larvae, in the British Museum.

*Type Locality*: Western part of Ceram.

The principal differential characters of this species are as follows: The hind femora are pale on the outer lateral surface to the apex, the basal sternites are wholly pale and sternites III (or IV) to VI are largely pale with a narrow black apical border, and V and VI have a narrow black basal border as well; VII is black with a narrow white sub-apical band, and VIII may be wholly black or pale basally.

*Genitalia*. The male genitalia are distinctive. The basal lobe of the coxite bears a tuft of hairs at its base and three strong spatulate spines above. The style is curved, and has a row of about nine unequal teeth apically. The apical tooth is the longest and the rest are of progressively decreasing size to the most proximal.

The larva, in common with *A. milnensis* and *A. lacuum*, has the comb scales fringed, but no further differential characters can be gleaned from the description.

*Distribution*.—Only known with certainty from Ceram and Saparoea.

#### Key to Australasian Species of *Armigeres*.

1. Clypeus with lateral patches of silver scales dorsally; hind femora white to apex on outer lateral surface; venter with broad apical dark band on segment III ..... *A. breinli*  
Clypeus without scales, hind femora and venter various ..... 2
2. Venter pale-scaled except on sternite VII; hind femora pale to apex on outer lateral surface ..... *A. lacuum*  
Venter with obvious dark bands at junctions of segments ..... 3
3. Hind femora pale to apex on outer lateral surface, sternite VII black except for narrow sub-apical pale band ..... *A. denbesteni*  
Hind femora with pale band on outer lateral surface terminating before apex; sternite VII with well-marked central pale band ..... *A. milnensis*

The above key will serve to distinguish specimens of both sexes, but confirmation of identification may be obtained by examination of the male genitalia.

#### THEOBALDIA ATRA, n. sp.\*

*Types*: Holotype female, allotype male, one male and eight female paratypes in the Western Australian Museum, Perth, two male and eight female paratypes in the collection of the Western Australian Department of Agriculture and two male and four female paratypes in the C.S.I.R. Museum, Canberra, A.C.T. All the specimens constitute a series bred from larvae by P. N. Forte.

*Type Locality*: Perth, Western Australia.

#### DESCRIPTION.

##### *Female*.

*Head*. The head has a border of pale, narrow curved scales in front along the eye margins, lateral patches of flat pale scales, and dorsally very narrow elongate dark brown upright forked scales are intermingled with a few narrow curved pale scales. The antennae are almost as long as the proboscis, the pedicels and flagella are dark brown; the verticillate hairs are also dark brown. The clypeus is dark brown, the palpi

\* Freeborn and Brockman in "Identification Guide to the Mosquitoes of the Pacific Coast States", United States Public Health Service, 1943, regard the generic name *Theobaldia* as invalid and have replaced it by *Culiseta*. The evidence on which this change is based is not available to me so for the present I have retained the more widely used name.

and proboscis are clothed with dark brown scales; the labella are yellowish; the palpi are only about one-tenth the length of the proboscis.

*Thorax.* The mesonotum is dark brown, clothed with black bristles and sparse fine dark bronzy-brown, hair-like scales. The scutellum is also dark brown with a few pale, narrow curved scales and six or seven long black border bristles on the mid-lobe; there are usually seven similar bristles on the lateral lobes. The postnotum is dark brown. The pronotal lobes are dark brown, and clothed with black bristles and hairs only. The posterior pronotum is dark brown. The rest of the pleurites are brown to dark brown; two to four strong black spiracular bristles are present; the post-spiracular area is bare; there is a continuous row of black bristles and hairs along the posterior border of the sternopleuron, mingled with a few scattered pale scales and at least one of the bristles in the lower sternopleural position is longer and stronger than the rest. One strong, and one weak lower mesepimeral bristle is present, and there are also a group of pre-alar and sub-alar bristles. The propleuron carries a tuft of six or more strong dark bristles. The halteres are light brown to dark brown.

*Legs.* The coxae and trochanters are brown, the fore coxae are clothed with dark brown scales anteriorly, the hind coxae with pale yellowish scales laterally, the rest of the legs are entirely dark-scaled, except for the under surface of the femora.

*Wings.* The wings are entirely clothed with dark brown scales. These are rather broader and more close-set on the costa, sub-costa,  $R_1$  and  $Cu_1$ . The upper fork cell is about five times as long as its stem, with its base considerably nearer the base of the wing than that of the lower fork cell, the stem of which is about two-thirds the length of the cell. The under surface of the base of the sub-costa (proximal to the humeral cross-vein) bears a tuft of hairs.

*Abdomen.* Dorsally the abdomen is clothed with black scales with violet reflections in some lights, and the venter is clothed with pale yellowish scales. It is hairy both dorsally and laterally.

#### *Male.*

Essentially the male is similar to the female except that the antennae are plumose; the palpi are longer than the proboscis by about half the apical segment; the antennae are about three-quarters the length of the proboscis. They are clothed with dark scales and hairs except for indistinct ventral patches of pale scales on segments II and III. There are also considerably fewer upright forked scales on the dorsal surface of the head.

*Genitalia* (Fig. 14). The coxites are long and tapering with their basal lobes rather small and hairy, but with a rather dark strongly spinose area dorsally near the base. The styles are straight, tapering, with a rather prominent terminal peg. The tenth sternites are strongly chitinized, terminating in three strong curved teeth; the phallosome is chitinized and similar to that of *T. inconspicua*. The lobes of the ninth tergite have three or four spines on each lobe.

*Note:* Although the Australian species of the genus *Theobaldia* are quite distinctive in characters of the male genitalia, the separation of females is undoubtedly difficult. In the present case it should prove fairly easy to recognize *Theobaldia atra* by its dark, well-developed spiracular bristles and the generally darker thoracic integument. The rest of the Australian species have fine, pale and inconspicuous spiracular bristles, and light brown or reddish thoracic integument.

#### CULEX POSTSPIRACULOSUS, n. sp.

*Types:* Holotype male, allotype female, one paratype of each sex, together with associated larval and pupal skins and a morphotype larva, all lodged in the C.S.I.R. Museum, Canberra, A.C.T.

*Type locality:* Narrabeen, N.S.W.

#### *Male.*

*Head.* Dorsally, the head is clothed with pale narrow curved scales intermingled with black upright forked scales giving place along the anterior border to brown, narrow, curved scales, and laterally to patches of flat pale scales. The antennae are normally

plumose and almost as long as the proboscis. The pedicels of the antennae are dark brown; flagellar segments I-XI are pale with dark brown rings at the bases of the verticillate hairs and the last two segments are elongate and dark brown. The palpi are longer than the proboscis by almost the whole of the two apical segments; they are dark brown scaled with pale junctions to the segments, and distinctly hairy from the distal half of the third segment to the apex. The proboscis is dark brown scaled with a rather indefinite pale scaled area, more readily visible from the undersurface, just beyond midway.

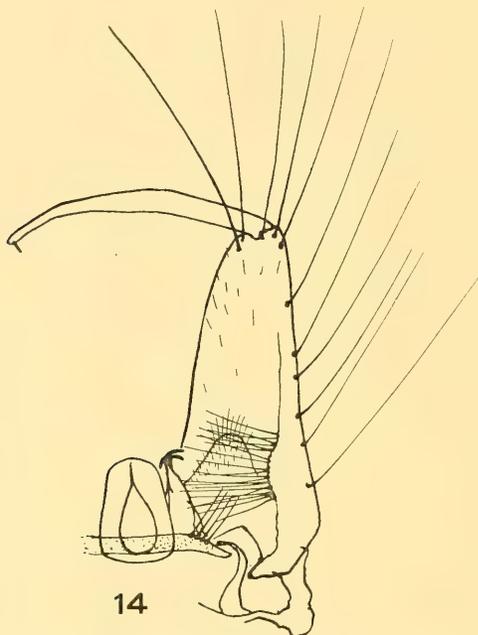


Fig. 14.—Genitalia of *Theobaldia atra*,  $\times 197$ .

*Thorax.* The scutal integument is dark brown, covered with bronzy-brown, narrow, curved scales and black bristles. The scutellum is dark brown, with groups of narrow curved golden-brown scales on the mid and lateral lobes; the border bristles are black. The postnotum is dark brown. The pleurae are completely dark brown; the pronotal lobes bear black bristles; the posterior pronotum has a posterior row of six or seven black bristles and a few bronzy-brown narrow scales. The propleuron bears a dense tuft of black bristles. There are at least two, often four, obvious postspiracular bristles; the sternopleuron bears a posterior row of brown bristles with one considerably stronger and longer black one about midway; there are a few pale silvery flat scales amongst the lower and upper sternopleural bristles. The pre-alar tuft comprises black bristles. The mesepimeron is bare in its lower region but has a tuft of pale sub-alar hairs mingled with a few pale scales.

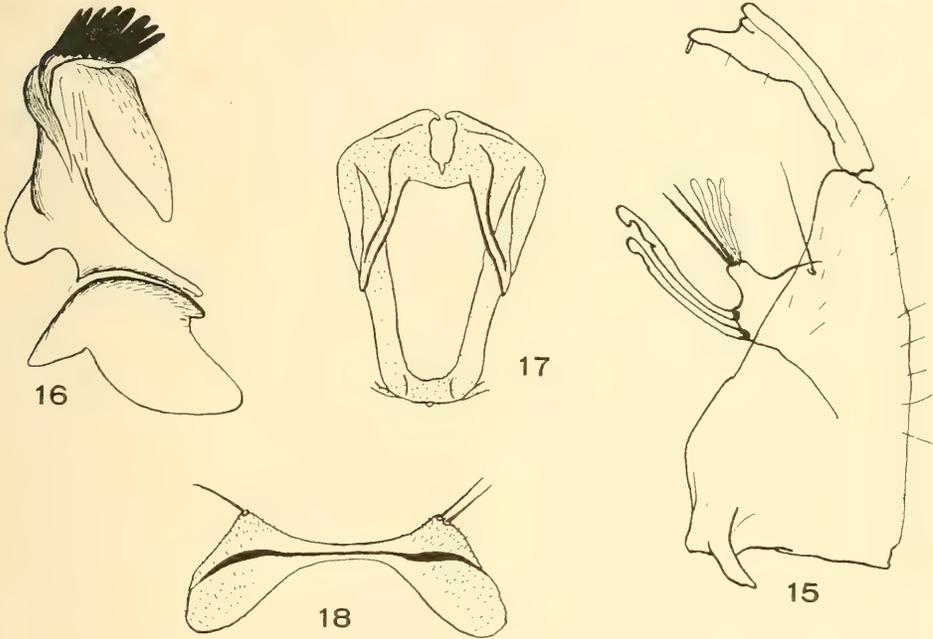
The halteres are yellowish-brown stemmed with darker knob.

*Legs.* The coxae and trochanters are dark brown. The rest of the legs are largely dark-scaled, except that on the forelegs there are narrow, pale basal bands on tarsal segments II and III; on the mid-legs, tarsi I, II and III have narrow pale basal rings; on the hind-legs similar rings are obvious at the bases of segments I-IV; the junctions on the femora and tibiae on all legs are pale-scaled.

*Wings.* The wing is clothed with dark brown scales; the upper fork cell is only very slightly longer than its stem, and the lower fork cell slightly shorter than its stem; their bases are equidistant from the base of the wing. The upper and middle cross-veins are in line with one another and distinctly distal to the lower cross-vein.

*Abdomen.* Segment I is dark brown; segment II has a sub-basal narrow pale band; the rest of the abdomen is black scaled with straight basal pale bands on each segment and long, fairly dense hairs laterally and apically on each segment. Ventrally the abdomen is dark brown scaled with lateral lines of pale scales on the apical segments.

*Genitalia* (Figs. 15-18). The coxites are broad at the base, narrowing rather sharply to the apex. There is an apical lobe divided into two sections bearing modified spines as illustrated in Fig. 15, and the style is distended apically. Fig. 16 shows the form of the tenth sternite, Fig. 17 the phallosome and Fig. 18 the ninth tergite.



Figs. 15-18.—Structures of the genitalia of *Culex postspiraculosus*. 15. Coxite and style,  $\times 160$ . 16. Tenth sternite,  $\times 1080$ . 17. Phallosome,  $\times 1080$ . 18. Ninth tergite,  $\times 1080$ .

#### *Female.*

*Head.* The head is dark brown with a median patch of pale narrow curved scales anteriorly and smaller brown narrow curved scales behind. There are lateral patches of flat pale scales, and a few pale scales are to be found anteriorly at the eye junction. The upright forked scales are very dark and numerous. The pedicels are dark brown, the antennae are dark brown with dark verticillate hairs and lighter, fine, short clothing hairs. The clypeus is dark brown and the palpi, which are about one-seventh the length of the proboscis, are black-scaled with a few pale scales at the tip.

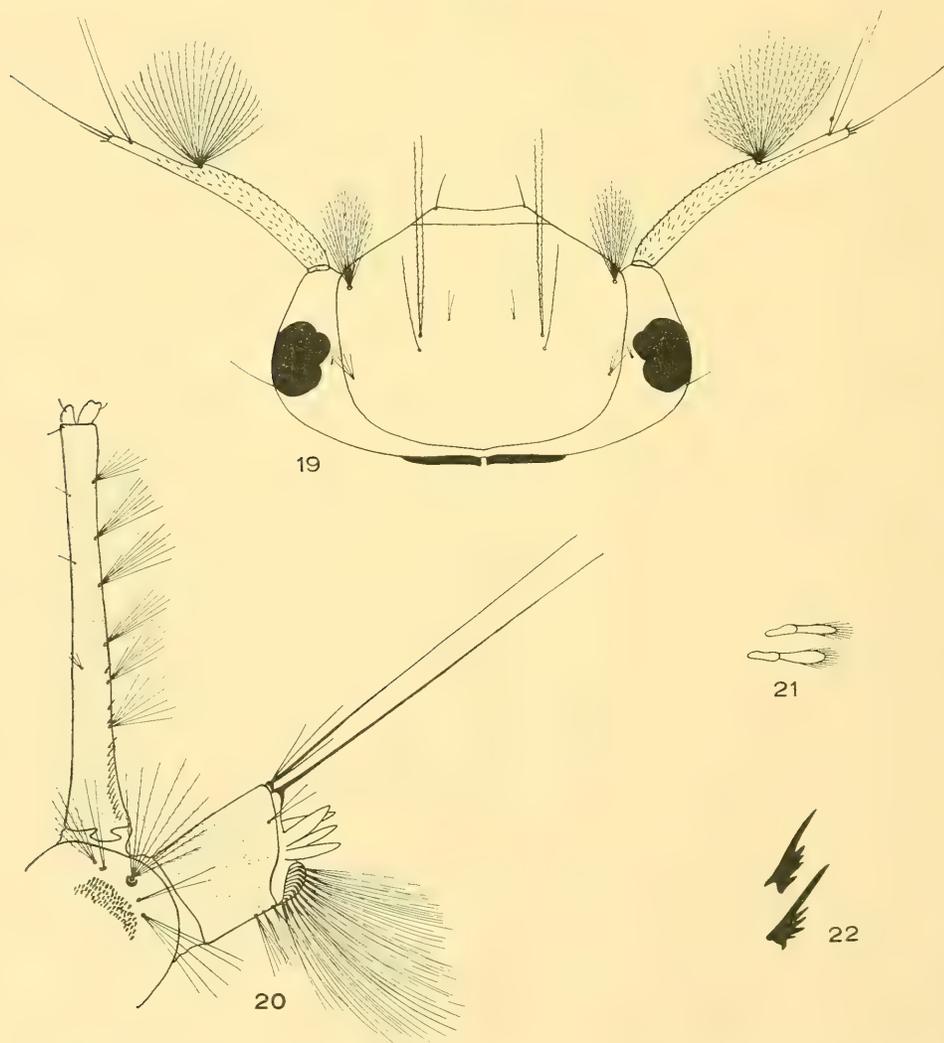
The proboscis is brown beneath the palpi, thence to about one-third from the tip pale-scaled, and the apical third is black. The pale-scaled area is somewhat more marked ventrally.

*Thorax.* The scutum is dark brown and clothed with small bronzy narrow curved scales; the scutellum is almost black with some narrow curved bronzy scales on the mid and lateral lobes. The bristles of the scutum and the border bristles of the scutellum are black. The postnotum is brown. The pronotal lobes are dark brown with black bristles; the posterior pronotum has bronzy narrow curved scales dorsally and posteriorly and black posterior bristles. The pleurae are uniformly dark brown. Spiracular bristles are absent, but the postspiracular area carries a group of four or five bristles and a few pale scales. There are tufts of pale scales among the lower and upper sternopleural bristles. Lower mesepimeral bristles are absent, but uppers are numerous and pale, and intermingled with a few pale scales.

*Legs.* The fore and mid coxae have a few pale scales near their base. The femora are pale-scaled beneath almost to the tip, otherwise they are dark-scaled, but with a few pale scales at their apices forming a small knee-spot. The tibiae are dark-scaled. There is a narrow ring of pale scales at the bases of segments II, III and IV of the tarsi of the fore- and mid-legs. The hind-legs have narrow basal pale rings on segments I-IV. Pulvilli are present and obvious.

*Wings.* The costa, subcosta,  $R_1$ , the base of the media, the greater part of the cubitus and the base of the anal vein are clothed with flat, broad dark scales; the rest of the wing veins bear elongate dark scales. The first fork cell is narrower and longer than the second, its base slightly nearer to the base of the wing than that of the second. The stem of the first fork cell is a little more than half the length of the cell and that of the second is almost as long as its cell. The squames have a dense fringe.

*Abdomen.* The abdomen is dark, the first segment has a few dark scales at the centre, segments II-VIII have basal bands of pale scales but are otherwise black-scaled. The pale bands on segments II-IV are practically straight, on V and VI slightly produced



Figs. 19-22.—Larval structures of *Culex postspiraculosus*. 19. Dorsal view of head,  $\times 32$ . 20. Terminal segments,  $\times 32$ . 21. Lateral comb scales,  $\times 200$ . 22. Pecten spines,  $\times 200$ .

in the middle, and on VII and VIII they are again straight. There are also a few pale scales at the lateral borders of the tergites, these forming pronounced patches continuous with the dorsal bands on segments VI and VII. The venter is clothed with black scales, but there are basal patches of pale scales laterally.

#### Larva.

The larva of *C. postspiraculosus* is a very dark, long-siphoned one, which is rather obvious when alive because of the white central area of the antennae contrasting markedly with the general black colouration.

*Head* (Fig. 19). The head is dark; the antennae are dark at the base and beyond the shaft-hair, but pale in between. The clypeal spines are rather long and fine; head hair A is multi-branched and plumose; B is bifid and finely frayed; C is simple with very sparse and fine fraying (not easily seen even under high magnification); d is short and bifid; e is about four-branched and short, and f is short and bifid. The antennae are distinctly spinose, the pre-apical bristles and terminal spines are long and very dark, and the shaft hair is strongly branched and plumose.

*Terminal segments* (Fig. 20). The lateral comb consists of 80 or more fringed scales (Fig. 21) in a roughly triangular group. Of the pentad hairs, the first has four to six plumose branches, the second is simple, the third has eight plumose branches, the fourth is simple, and the fifth has four or five plumose branches. The siphon is long, with six pairs of multi-branched ventro-lateral tufts. The pecten extends from the base to beyond the second ventro-lateral tuft and its spines are pectinate (Fig. 22). A distinct acus is present. The siphonal index is about 6. The saddle is a continuous ring with a bifid saddle hair. The dorsal sub-caudal tuft is characteristically as illustrated, with one long and three short hairs and the ventral sub-caudal tuft is single. The anal papillae are scarcely half the length of the saddle and there are two or three precratal tufts present on the ventral brush.

Although superficially resembling *C. sitiens* and *C. annulirostris*, this species is immediately distinct, in the larval stage, by its head hairs. Furthermore, the form of the dorsal sub-caudal tuft and the presence of precratal tufts are unusual features.

*Habitat*. The larvae were found breeding in a very shallow brackish swamp amongst a dense growth of tall reeds near Narrabeen, N.S.W.

*Distribution*.—This is a commonly found species in the vicinity of the type locality, but I have also seen specimens from Brisbane.

*Note*: In almost all respects, particularly in the male genitalia, the presence of pulvilli in the female, and larval characters, this species conforms to the definition of the genus *Culex*. In possessing post-spiracular bristles, it differs from all other known species of the genus *Culex*, and hence the adult might readily be misidentified generically.

#### Acknowledgements.

I am indebted to Sgt. D. A. C. Cameron for a collection of specimens of *Armigeres*, which was particularly valuable because of the care with which he correlated larval and adult material; to the Director, School of Public Health and Tropical Medicine, Sydney, for permission to examine type material in the Collection of the School and to C. F. H. Jenkins and P. N. Forte for the provision of the material of the new species of *Theobaldia*.

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## STUDIES ON AUSTRALIAN MARINE ALGAE. I.

THE CORRECTED NAME FOR *PTEROCLADIA PECTINATA* (A. & E. S. GEPP) LUCAS.

By VALERIE MAY, M.Sc. (C.S.I.R., Marine Biological Laboratory, Cronulla, N.S.W.).

(Six Text-figures.)

[Read 29th November, 1944.]

*GELIDIUM LUCASII*, new name.

Syn.: *Pterocladia lucida* f. *pectinata* A. & E. S. Gepp, *J. Bot.*, xliv, 1906. *Pterocladia pectinata* (A. & E. S. Gepp) Lucas, *Proc. Linn. Soc. N.S.W.*, lvi, 1931. Not *Gelidium pectinatum* Montagne, *Hist. Nat. des Iles Canaries*, iii (2), 1840.

In Maroubra Bay, near Sydney, New South Wales, in July, 1901, A. H. S. Lucas collected an alga (No. 9) of which he sent part to A. & E. S. Gepp; part is also retained at the National Herbarium, Sydney. In 1906, A. & E. S. Gepp described this alga as *Pterocladia lucida* f. *pectinata*, but did not refer to any of the reproductive structures. The specimen labelled No. 9 at the National Herbarium, which is doubtless part of the type collection, shows the presence of tetraspores; other specimens collected at the same time are freely tetrasporic.

In the same locality in 1910, Mr. Lucas found cystocarpic material of this plant, and in 1931, he published a description in which he raised the plant to specific rank. No further publication on this species has appeared.

Due to recent collections by the writer, samples of this species are available now in quantity sufficient to enable a more adequate examination of it to be made. From this examination, and a re-examination of all Lucas' material (National Herbarium, Sydney, and Lucas Collection, Council for Scientific and Industrial Research, Canberra), it now seems that *Pterocladia pectinata* (A. & E. S. Gepp) Lucas should be referred to the genus *Gelidium*, and as the name *Gelidium pectinatum* is already in use, I now propose for it the name *Gelidium Lucasii*, in honour of Mr. A. H. S. Lucas, who was for many years Australia's foremost worker on algae, and who first collected the plant under discussion.

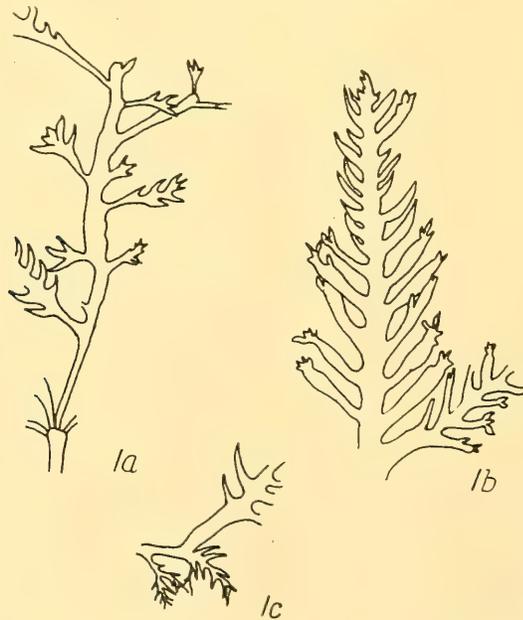


Fig. 1.—*Gelidium Lucasii*, new name. Habit. [See also photograph in Lucas (1931).] 1a, near base,  $\times \frac{5}{12}$ ; 1b, at apex,  $\times \frac{4}{5}$ ; 1c, attachment region,  $\times \frac{5}{12}$ . (All magnifications are approximate only; sizes vary greatly in any individual plant.)

The distinction between the genus *Pterocladia* and the genus *Gelidium* is that the cystocarp is unilocular in the former and bilocular in the latter. In all the cystocarpic material of the plant under discussion examined, the cystocarps are bilocular (Fig. 5).

Though it has generally been considered in the past that the cystocarpic distinction is the only one between these allied genera, Okamura (1934) in Japan has tried to link the anatomical to the cystocarpic characters, and says that in cross-sections of the thallus, filaments are more evident towards the centre in *Pterocladia*, and toward the periphery in *Gelidium*. However, in making this rule, he admits there are many exceptions. The present species is such an exception, in that there are filaments present in the central tissue. Okamura (loc. cit.) further claims that in *Gelidium* the tetrasporic sorus is strictly limited with a sharply defined boundary, while in *Pterocladia* the sorus is less clearly defined. The sorus of *G. Lucasii* (Fig. 6b) is of the form described for *Gelidium*. Thus the cystocarp determines that the plant is, in fact, a *Gelidium*, and this is in accordance with the structure of the tetrasporic sorus.

From a study of the literature it would appear that *G. Lucasii* is near *G. subcostatum* Okamura (figured in Okamura, 1907). Both have the frond compressed, two-edged

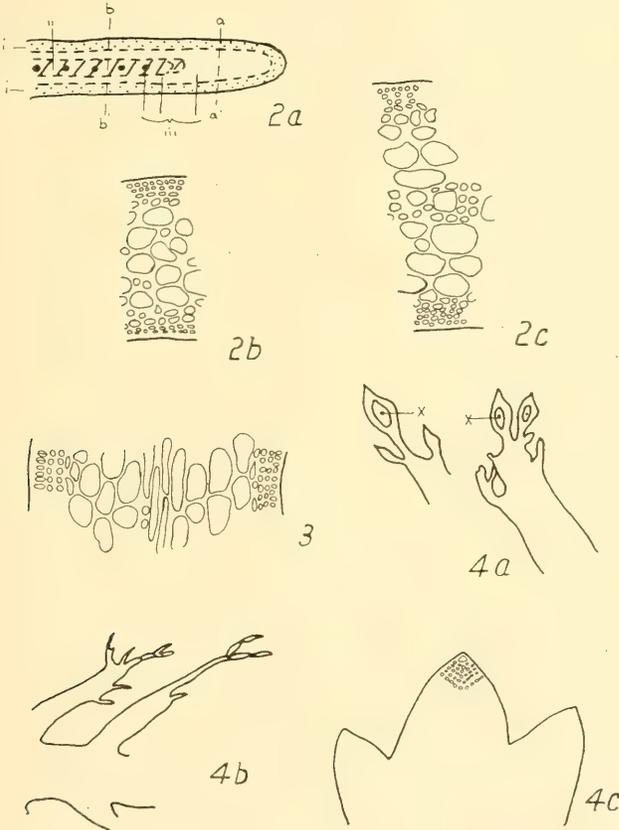


Fig. 2.—*Gelidium Lucasii*, new name. Transverse sections of thallus. Periphery (i) is of small coloured cells, while other cells have thick, mucilaginous walls. Filaments (ii) have granular contents; larger cells (iii) are relatively clear. 2a, diagrammatic representation of transverse section of thallus; 2b, transverse section of thallus along line b-b', × 225; 2c, transverse section of thallus along line a-a', × 225.

Fig. 3.—*Gelidium Lucasii*, new name. Longitudinal section of thallus in region b-b' of Fig. 2a, × 225.

Fig. 4.—*Gelidium Lucasii*, new name. Cystocarpic branches. 4a, apices of branches (cystosporangia) which bear cystocarps, × 5; x = ostiole. 4b, apices of old branches which have produced cystocarps, × 5. 4c, apex of young cystosporangium showing apical cell. This apical cell is soon lost from vegetative apices, but is obvious in both cystosporangium and tetrasporangium, × 150. (All magnifications are approximate only.)

distichously pinnate and of similar structure, but the Australian plant may be distinguished easily from the Japanese plant, for the latter develops a distinct midrib and the pinnae are very much shorter in comparison with branch width, than is the case in *G. Lucasii*.

The distribution of *G. Lucasii* appears very limited. We have records of it from:

Maroubra, near Sydney, N.S.W.	July, 1901	A. H. S. Lucas	Tetrasporic
" " " "	July, 1910	A. H. S. Lucas	Cystocarpic
Bondi, near Sydney, N.S.W.	—	S. E. Napier	Sterile only
East Cape, N.Z.	—	—	Cystocarpic
Collaroy Beach, near Sydney, N.S.W.	April, 1944	Valerie May	Few cystocarpic; many tetrasporic
" " " " "	May, 1944	Valerie May	Cystocarpic and tetrasporic
" " " " "	July, 1944	Valerie May	Cystocarpic and tetrasporic

There is also (National Herbarium, Sydney) a plant, "Loc. and coll. unknown", bearing cystocarps.

All records appear to be of plants washed ashore after heavy storms—all those collected at Collaroy were so—and the 1901 Maroubra material is reported as having been washed ashore after a southerly gale. Thus the species is evidently confined to deep water.

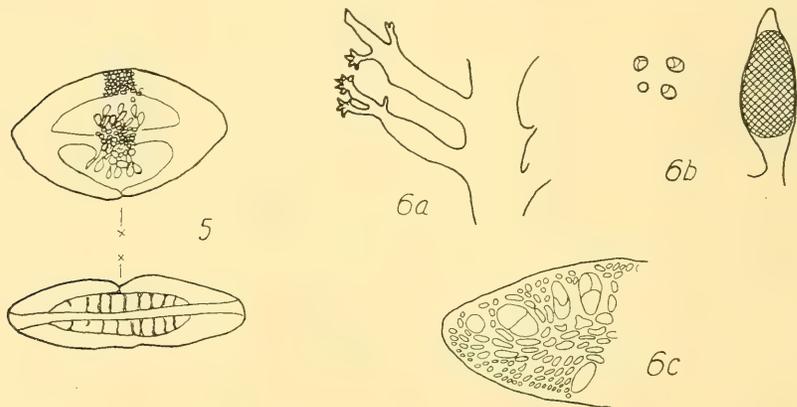


Fig. 5.—*Gelidium Lucasii*, new name. Transverse section of cystocarps showing bilocular structure and variation in shape; x = ostiole.

Fig. 6.—*Gelidium Lucasii*, new name. Tetrasporic material. 6a, branches (tetrasporangia) bearing tetraspores,  $\times 5$ ; 6b, a tetrasporangium, showing region which bears tetraspores arranged in irregularly decussate manner,  $\times 25$ , also surface section of tetraspores separated from parent plant,  $\times 125$ ; 6c, transverse section of tetrasporangium showing tetraspores in varying stages of development, i.e., of mixed ages,  $\times 225$ . (All magnifications are approximate only.)

It seems that the Sydney district and one locality in New Zealand are the only habitats recorded for this species. Since our knowledge of Australasian algae is only meagre, we should not, of course, be surprised if the range should prove to be much greater than is known at present.

Because of the present economic stimulus to investigations of the Gelidiales, it is hoped that we may learn more about their distribution.

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## NITROGEN FIXATION IN LEGUMINOUS PLANTS. V.

GAINS OF NITROGEN BY MEDICAGO AND TRIFOLIUM IN ACID AND ALKALINE SOIL.

By H. L. JENSEN, Macleay Bacteriologist to the Society.

*(From the Department of Bacteriology, University of Sydney.)*

[Read 25th October, 1944.]

*Introduction.*

It was shown in a previous paper (Jensen, 1943) that the reaction of the growth medium (sand or soil) influences the rate of nitrogen fixation in leguminous plants partly through its effect on the ability of the nodule bacteria to infect the plant roots, and partly through its effect on the activity of the nodules subsequently formed. The uptake of nitrogen per unit of dry nodule-substance was as a rule smaller at acid than at alkaline reaction, although the total yields of nitrogen were not always significantly different. The quantities of nitrogen that might have been taken from the medium or excreted into it from the roots were not taken into account. Another series of experiments has therefore been added, in which it has been attempted to give as accurate a balance-sheet of nitrogen as possible by analysis of the seed, the crop, and the growth medium which was represented by natural soil. Compared with pure sand, the use of natural soil has the advantage of showing the influence of reaction on the two separate sources from which leguminous plants normally derive their nitrogen supply under natural conditions—namely, on the process of nitrogen fixation in the root nodules and on the assimilation of combined nitrogen from the soil. Owing to its greater absorptive capacity, the natural soil is also likely to be more favourable for excretion of fixed nitrogen from the legume root systems, a process which under Australian climatic conditions does not normally take place in sand media, as shown by Trumble *et al.* (1937) and Swaby.\* On the other hand the method of analysing the soil before and after plant growth is very laborious and has been little used since the earliest investigations on symbiotic nitrogen fixation; experiments of this kind have been described by Albrecht (1920), Brown and Stallings (1921), Bjälfve (1935), and Engel and Roberg (1938), but only in one instance (Fred and Graul, 1916) are the experiments seen to involve modification of the soil reaction, and this was not expressed in terms of hydrogen ion concentration. Several other investigators have determined the amounts of nitrogen left in sand media by leguminous crops, but systematic experiments on the effect of reaction in this respect do not appear to have been made. Ludwig and Allison (1940) found no excretion of nitrogen from pea plants in sand of pH 6.4 to 7.7.

## METHODS.

Most experiments were done on lucerne (*medicago sativa*), and subterranean clover (*Trifolium subterraneum*), a few also on annual medics (*M. tribuloides* and *M. orbicularis*) and red clover (*T. pratense*). The culture vessels were mostly small glass jars of 4 in. diameter or wide-necked reagent bottles, holding 500 to 700 gm. of soil, but in one series glazed earthenware pots of 6 in. diameter were used. Admittedly the very small vessels provide conditions that do not come very near to the natural, but it was deemed advisable to accept this disadvantage in exchange for the great reduction in sampling error attached to the nitrogen determinations, which results from working with small portions of soil. The soils were used in a very finely ground condition and mixed with sand passing a 30-mesh sieve. Separate portions of soil and sand were weighed out for each vessel, and the mixtures were moistened to approximately 75% of the water-holding capacity. Only seeds uniform in appearance were sown, after inoculation with effective strains of the corresponding nodule bacteria. After sowing, the soil surface was covered with a mulch of clean, coarse gravel, and the sides of the

\* Personal communication.

glass vessels were protected from light by a wrapping of thick brown paper. During growth, the plants were kept in a greenhouse and watered with distilled water. At harvesting, the plant tops were cut off immediately above the soil surface, dried and weighed, the roots and the soil were separated as completely as possible, and nitrogen was determined by the Kjeldahl method with selenium as a catalyst. The roots were digested *in toto*, and the tops likewise if the amount of material was small; otherwise they were finely ground and aliquot samples taken. Soil was digested with equal parts of water and sulphuric acid, and with addition of reduced iron for reduction of any nitrate present. At least six replicate determinations were made on 10 to 25 gm. of soil, depending on the nitrogen content; care was taken to weigh out the soil for analysis in a moist condition in order to avoid segregation, and digestion was continued for three hours after the acid had become colourless. N/28 H<sub>2</sub>SO<sub>4</sub> and NaOH were used for the titrations, with methyl red plus methylene blue as indicator. The standard error of the mean N-content could in all except a few cases be kept well below 1%. Nitrate and ammonia were determined by the method of Richardson (1938).

## EXPERIMENTAL.

*Experiment No. 1.*—Lucerne and subterranean clover were grown in a soil of pH 5.4 and of moderate nitrogen content (769 p.p.m.), composed of three parts of sand mixed with one part of an acid loam very rich in humus and containing approximately 0.30% nitrogen; 0.05% CaHPO<sub>4</sub> and 0.01% KH<sub>2</sub>PO<sub>4</sub> were added as fertilizer, and 0.5% CaCO<sub>3</sub> was added to produce alkaline reaction. Small glass jars, each holding 600 gm. of dry soil and six plants, were used as culture vessels. Sowing took place on 14th August, 1941; lucerne was harvested after 91 and clover after 85 days. Both plants grew well and did not at any stage show visible differences according to soil reaction. Table 1 shows the nitrogen balance of crop and soil. The nitrogen content of soil is in this as in the following tables expressed on the basis of oven-dry soil.

TABLE 1.  
*Nitrogen Fixation by Lucerne and Subterranean Clover in Acid and Alkaline Soil.*

	Initial.	Final.			
		-CaCO <sub>3</sub> .		+CaCO <sub>3</sub> .	
		a.	b.	a.	b.
1. Lucerne.—pH of soil .. .. .	5.4	5.3	5.5	7.6	7.6
N in soil, mgm. .. .. .	451	442	437	436	426
„ „ seed, mgm. .. .. .	1.4	—	—	—	—
„ „ plant tops, mgm. .. .. .	—	44.9	39.2	59.7	53.6
„ „ „ roots, mgm. .. .. .	—	18.2	12.6	24.8	20.1
„ total, mgm. .. .. .	452.4	505.1	488.8	520.5	499.7
Net gain of N, mgm. .. .. .	—	52.7	36.4	68.1	43.7
N taken from soil, mgm. .. .. .	—	9±3.6	14±4.9	15±4.8	25±5.4
2. Clover.—pH of soil .. .. .	5.4	5.5	5.5	7.5	7.5
N in soil, mgm. .. .. .	451	449	437	428	425
„ „ seed, mgm. .. .. .	5.4	—	—	—	—
„ „ plant tops, mgm. .. .. .	—	69.3	79.1	62.8	66.3
„ „ „ roots, mgm. .. .. .	—	13.1	14.6	11.7	11.1
„ total, mgm. .. .. .	456.4	531.4	530.7	502.5	502.4
Net gain of N, mgm. .. .. .	—	75.0	74.3	46.1	46.0
N taken from soil, mgm. .. .. .	—	(2±3.0)	14±3.9	23±3.1	26±2.7
Production of NO <sub>3</sub> -N in soil after removal of plants, p.p.m.—					
After lucerne .. .. .	—	12.6	11.7	19.8	20.3
After clover .. .. .	—	12.2	12.6	23.7	21.3

The total nitrogen content of lucerne plants (tops plus roots) is only slightly higher at alkaline reaction, and this is accompanied by a somewhat larger uptake of combined nitrogen from the alkaline soil, so that the net gains of nitrogen at pH 5.3-5.5 and pH 7.6 are not significantly different; unfortunately, the agreement between the duplicate jars is not very good.

The corresponding figures for clover show quite a different picture. The total nitrogen content of the plants is slightly higher at acid reaction, but, as in lucerne, more combined nitrogen has been taken from the alkaline soil; in one of the jars with acid soil the decrease in nitrogen content of the soil is not even significant. As a result, the net gain of nitrogen is, at pH 5.5, more than 50% higher than at pH 7.5. Both plants thus draw more heavily on the soil nitrogen at alkaline reaction. This seems due to the fact that the addition of lime stimulated the mineralization of the humus nitrogen, as shown by a nitrification test on the residues of soil after removal of the plants. Soil samples were adjusted to approximately two-thirds water-holding capacity and incubated for 4 weeks at 30°C. Only traces of ammonia and nitrate were present at the start, and no ammonia accumulated during the incubation, while the production of nitrate was greatly stimulated where lime had been added, but was not significantly different after lucerne and clover (Table 1, bottom).

*Experiment No. 2.*—The experiment was repeated in bigger pots holding 2.5 kgm. of soil, which contained a higher proportion of sand, giving a nitrogen content of 478 p.p.m.; 0.1% superphosphate and 0.01% KCl were added as fertilizer, and 0.2% CaCO<sub>3</sub> was added to change the reaction to neutral. The soil was found to be somewhat more

TABLE 2.

*Nitrogen Fixation by Lucerne and Subterranean Clover in Acid and Alkaline Soil of Low Nitrogen Content.*

	Initial.	Final.			
		-CaCO <sub>3</sub>		+CaCO <sub>3</sub>	
		a.	b.	a.	b.
1. Lucerne.—pH of soil .. .. .	4.9	5.0	5.1	7.1	7.3
N in soil, mgm. .. .. .	1189	1118	1115	1079	1088
„ „ seed, mgm. .. .. .	4.0	—	—	—	—
„ „ plant tops, mgm. .. .. .	—	87.3	94.9	177.6	172.5
„ „ „ roots, mgm. .. .. .	—	48.2	62.2	120.6	108.0
„ total, mgm. .. .. .	1193.0	1253.5	1272.1	1377.2	1368.5
Net gain of N, mgm. .. .. .	—	60.5	79.1	184.2	175.5
N taken from soil, mgm. .. .. .	—	71±4.8	74±5.5	110±3.7	101±3.2
2. Clover.—pH of soil .. .. .	4.9	5.1	5.1	7.2	7.5
N in soil, mgm. .. .. .	1189	1106	1111	1082	1098
„ „ seed, mgm. .. .. .	18.0	—	—	—	—
„ „ plant tops, mgm. .. .. .	—	197.5	186.7	192.3	182.1
„ „ „ roots, mgm. .. .. .	—	53.2	51.4	45.6	55.2
„ total, mgm. .. .. .	1207.0	1356.7	1349.1	1319.9	1335.3
Net gain of N, mgm. .. .. .	—	149.7	142.1	112.9	128.3
N taken from soil, mgm. .. .. .	—	83±4.7	78±6.3	107±5.5	91±4.4
3. Wheat.—pH of soil .. .. .	4.9	5.2		7.2	
N in soil, mgm. .. .. .	1189	1115		1080	
„ „ seed, mgm. .. .. .	6	—		—	
„ „ plants, mgm. .. .. .	—	60		71	
„ total, mgm. .. .. .	1195	1175		1151	
Net loss of N, mgm. .. .. .	—	20±5.9		44±6.4	

acid than in the previous experiment (pH 4.9). One additional pot with acid and one with neutral soil were sown with wheat to serve as controls on possible non-symbiotic nitrogen fixation. Lucerne was sown on 30th April, clover on 4th May, and wheat on 1st May, 1942; the plants were harvested after 121, 102, and 134 days, respectively. Each pot carried twelve plants of lucerne, six of clover, and eight of wheat. In this experiment the growth of lucerne was definitely better in the neutral soil, while the clover, as before, showed no visible difference. The wheat grew poorly, showed signs of nitrogen starvation, and suffered badly from rust in the neutral soil. When the roots were collected, the nodules on clover appeared similar at both reactions, while those on lucerne in acid soil were fewer and bigger than in neutral soil, and largely of the branched or multiple type, as observed before (Jensen, 1943). Table 2 shows the analytical data.

The lucerne plants in acid soil contain only about half as much nitrogen as at neutral reaction, and the net gain of nitrogen is, at pH 5.0-5.1, only some 40% of what it is at pH 7.1-7.3, although the soil nitrogen is again utilized more strongly at neutral reaction. By comparison with the previous experiment, it appears that the interval from pH 4.9-5.1 to pH 5.4-5.5 represents the range where the acidity begins to exert a marked depressing influence on nitrogen fixation in lucerne. This agrees with the fact that the same range of pH was found critical for nodule formation on lucerne in agar culture (Jensen, 1943), and that Olsen (1925) observed a big increase in yield of lucerne when the soil pH was raised from 5 to 6. Olsen's results, however, were obtained from soil of high humus content and supplied with nitrate, so that we can form no idea of the actual gains of nitrogen.

The clover has given the same gross yield of nitrogen at both reactions, and the larger uptake of nitrogen from the neutral soil results, as in the previous experiment, in a somewhat (roughly 20%) higher net gain of nitrogen at pH 4.9-5.1.

The pots with wheat give no indication of any non-symbiotic nitrogen fixation; on the contrary there is a small but significant net loss of nitrogen. The cause of this loss seems uncertain, but might possibly consist in the occurrence of denitrification before the plants had reached sufficient development to use up the  $\text{NO}_3\text{-N}$  present at the start (5.8 p.p.m., or 14.5 mgm. per pot) and produced during the early stages of the experiment (cf., Engel and Roberg (1938), who in unplanted soil in a pot experiment observed a small loss of nitrogen, which they ascribed to denitrification). The question whether such a loss of nitrogen may also have occurred in the soil under the leguminous plants, and whether this may not be the real cause of the stronger decrease in nitrogen content of neutral or alkaline soil, is of course impossible to answer on the basis of the available data. It would seem that experiments involving the use of isotopic nitrogen as a tracer-element would be needed to supply the final answer.

*Experiment No. 3.*—This included the two annual medics and red clover. The plants were grown in a mixture of soil and sand similar to Exp. No. 1, with addition of 0.1% superphosphate and 0.005%  $\text{KH}_2\text{PO}_4$ , besides 0.4%  $\text{CaCO}_3$  to give alkaline reaction. The nitrogen content was 744 p.p.m., but the reaction was found more acid than in the first experiment (initial pH 4.6). The culture vessels were wide-necked reagent bottles of 500 c.c. capacity, each holding 4 plants and 540 gm. of soil. *Medicago tribuloides* was sown on 23rd February, *M. orbicularis* on 24th February, clover on 20th February, 1942, and the plants were harvested after 73, 86, and 115 days, respectively. The two medics, but particularly *M. tribuloides*, grew poorly in the acid soil, where the red clover on the other hand showed better growth than in the alkaline.

The analytical data in Table 3 show that the two medics, in spite of their scanty growth, had fixed certain amounts of nitrogen in this strongly acid soil, but the net gains of nitrogen at the final pH of 5.0-5.2 reach only one-fifth to one-fourth of the gains at pH 7.1-7.4. As in the previous experiments, more nitrogen is taken from the alkaline soil. The red clover shows a surprising result: the total nitrogen content of the plants is about twice, and the net gain nearly three times, as high at pH 4.9 as at pH 7.3-7.4. Although the result suggests a definite preference of red clover for acid soil reaction, one must necessarily hesitate to accept this as indicating anything like a general rule.

TABLE 3.  
*Nitrogen Fixation by Annual Medics and Red Clover in Acid and Alkaline Soil.*

	Initial.	Final.			
		-CaCO <sub>3</sub>		+CaCO <sub>3</sub>	
		a.	b.	a.	b.
1. <i>Medicago tribuloides</i> .—pH of soil .. ..	4.6	5.0	5.2	7.2	7.2
N in soil, mgm. .. ..	398	390	392	386	384
„ „ seed, mgm. .. ..	1.6	—	—	—	—
„ „ plant tops, mgm. .. ..	—	13.1	13.0	34.0	36.4
„ „ „ roots, mgm. .. ..	—	3.0	1.7	5.4	6.0
„ total, mgm. .. ..	399.6	406.1	406.7	425.4	426.4
Net gain of N, mgm. .. ..	—	6.5	7.1	25.8	26.8
N taken from soil, mgm. .. ..	—	8±2.0	6±2.2	12±2.2	14±1.9
2. <i>Medicago orbicularis</i> .—pH of soil .. ..	4.6	5.1	5.0	7.3	7.4
N in soil, mgm. .. ..	398	386	392	385	379
„ „ seed, mgm. .. ..	1.2	—	—	—	—
„ „ plant tops, mgm. .. ..	—	26.7	14.2	64.6	60.9
„ „ „ roots, mgm. .. ..	—	3.6	1.3	12.0	13.6
„ total, mgm. .. ..	399.2	416.3	407.5	461.6	453.5
Net gain of N, mgm. .. ..	—	17.1	8.2	62.4	54.3
N taken from soil, mgm. .. ..	—	12±5.0	(6±3.7)	13±3.6	19±3.5
3. <i>Trifolium pratense</i> .—pH of soil .. ..	4.6	4.9	4.9	7.3	7.4
N in soil, mgm. .. ..	398	392	386	387	382
„ „ seed, mgm. .. ..	1.0	—	—	—	—
„ „ plant tops, mgm. .. ..	—	49.2	34.0	23.0	23.4
„ „ „ roots, mgm. .. ..	—	12.7	11.3	4.8	5.4
„ total, mgm. .. ..	399.0	453.9	431.3	414.8	410.8
Net gain of N, mgm. .. ..	—	54.9	32.3	15.8	11.8
N taken from soil, mgm. .. ..	—	(6±3.0)	12±3.5	11±3.9	16±3.0

This experiment also included jars sown with *Medicago minima* which made only a slow, and in the acid soil an extremely poor, growth. Nitrogen in the soil was not determined, but analysis of plants 20 weeks old showed the following contents of nitrogen:

	-CaCO <sub>3</sub>		+CaCO <sub>3</sub>	
	a.	b.	a.	b.
Final pH of soil .. ..	5.1	5.1	7.4	7.4
N in tops, mgm. .. ..	8.9	5.1	44.6	43.2
„ „ roots, mgm. .. ..	0.6	0.5	5.4	6.9

*M. minima* thus seems even more sensitive to acidity than the two other annual medics, a property which was also suggested by tests on nodule formation in agar culture (Jensen, 1943).

*Experiment No. 4.*—Lucerne and subterranean clover were grown, at two different times, in soil of extremely low nitrogen content (122 p.p.m.), consisting of a fine sandy loam very poor in humus and mixed with sand in the ratio of two parts of soil to five parts of sand; 0.2% CaCO<sub>3</sub> was added to give neutral reaction. Lucerne was sown on 25th June, 1942, in 4 in. glass jars holding 6 plants and 700 gm. of soil with addition of 0.1% superphosphate, and harvested after 90 days, when the plants in the acid soil appeared considerably smaller than those in the neutral soil, and carried fewer and bigger root nodules. Clover was grown in somewhat smaller jars holding only two plants and 450 gm. of soil with 0.02% KH<sub>2</sub>PO<sub>4</sub> and 0.02% CaCl<sub>2</sub>. The plants were sown on 12th April, 1943, and harvested after 144 days; the root nodules were collected, weighed and analysed separately. There were no visible differences in the general appearance of

the plants or the type of nodulation in acid and neutral soil. Table 4 shows the analytical data.

TABLE 4.  
*Nitrogen Fixation by Lucerne and Subterranean Clover in Acid and Neutral Soil of Very Low Nitrogen Content.*

	Initial.	Final.			
		-CaCO <sub>3</sub>		+CaCO <sub>3</sub>	
		a.	b.	a.	b.
1. Lucerne.—pH of soil .. .. .	5.1	5.2	5.4	7.2	7.1
N in soil, mgm. .. .. .	86.0	84.2	84.7	83.4	85.3
„ „ seed, mgm. .. .. .	1.4	—	—	—	—
„ „ plant tops, mgm. .. .. .	—	25.1	24.0	44.3	42.0
„ „ „ roots, mgm. .. .. .	—	10.0	9.5	20.3	23.1
„ total, mgm. .. .. .	87.4	119.3	118.2	148.0	150.4
Net gain of N, mgm. .. .. .	—	31.9	30.8	60.6	63.0
N taken from soil, mgm. .. .. .	—	1.8±0.4	1.3±0.4	2.6±0.4	(0.7±0.7)
2. Clover.—pH of soil .. .. .	5.0	4.7	4.8	7.0	7.1
N in soil, mgm. .. .. .	54.4	59.4	64.8	58.0	61.2
„ „ seed, mgm. .. .. .	2.2	—	—	—	—
„ „ plant tops, mgm. .. .. .	—	72.3	64.9	70.1	82.6
„ „ „ roots, mgm. .. .. .	—	9.6	9.9	8.0	12.1
„ „ „ nodules, mgm. .. .. .	—	9.3	7.9	3.3	3.1
„ total, mgm. .. .. .	56.6	150.6	147.5	139.4	159.0
Net gain of N, mgm. .. .. .	—	94.0	90.9	82.8	102.4
Gain of N to soil, mgm. .. .. .	—	5.0±0.8	10.4±1.1	3.6±0.7	6.8±0.7
Dry weight of tops, gm. .. .. .	—	2.317	1.921	2.149	2.221
„ „ „ roots, gm. .. .. .	—	0.342	0.342	0.279	0.427
„ „ „ nodules, gm. .. .. .	—	0.135	0.123	0.053	0.041
Net gain of N per gm. of dry nodule-substance .. .. .	—	696	749	1562	2497

As in Experiment No. 2, the nitrogen content of lucerne at pH 5.1–5.4 is very nearly one-half of that at pH 7.1–7.2, but almost all of it represents net gain at both reactions, because the uptake of nitrogen from the soil is very small, and in one of the jars not even significant, although the soil originally contained 4.2 p.p.m., or 2.9 mgm. per jar, of (NO<sub>3</sub> + NH<sub>4</sub>)N. The yield of nitrogen by subterranean clover is the same at acid and neutral reaction, and the nitrogen content of the soil has actually increased during the growth of the plants. It is difficult to say whether this increase is due to active excretion of fixed nitrogen, to decayed nodules and root fragments, or to both sources. The second cause might seem probable in view of the long growth period and the fact that many authors (Bjälfeve, 1935; Trumble *et al.*, 1937; Nowotnowna, 1937; Bond, 1938, 1941; Bond and Boyes, 1939; Scholz, 1939; Wyss and Wilson, 1941) have after growth of leguminous plants in sand medium observed small increases in the nitrogen content of the sand; these increases were ascribed to detached fragments of the root systems, which are virtually impossible to separate from the medium. On the other hand the increases in soil nitrogen observed in the present instance are of an order of one-third to one-half of all the nitrogen in roots plus nodules, which seems rather more than one would expect from this source, particularly as the root systems looked healthy and showed no signs of decay. We can thus hardly go further than to say that in this single experiment it is possible but by no means certain that a small proportion, not exceeding 10%, of the fixed nitrogen has been excreted from the roots. The fact that no significant decrease in the nitrogen content of the soil took place in

one of the lucerne jars as well as in a few previous cases (Tables 1 and 3), although the medium originally contained certain amounts of nitrate which had disappeared at harvesting, might well be due to small root fragments being left behind in the soil.

The weight of the clover nodules, both absolutely and as percentage of total dry weight, is considerably smaller in neutral soil, as also observed before (Jensen, 1943); this is due to a smaller average size of individual nodules, since the numbers of nodules per plant were not significantly different in acid and alkaline soil. The efficiency of the nodules, expressed as net gain of nitrogen per unit weight of nodule substance, is seen to be two to three times higher at pH 7.0-7.1 than at pH 4.7-4.8.

The following percentages of nitrogen in dry matter of plant tops were found in the different experiments:

			Acid Soils. (pH 4.7-5.5)	Alkaline Soils. (pH 7.0-7.7)
<i>Medicago sativa</i>	(Exp. 1)	.. ..	3.39-3.44	3.32-3.59
" "	( " 2)	.. ..	3.23-3.28	3.64-3.77
" "	( " 4)	.. ..	3.50-3.70	4.10-4.24
<i>M. tribuloides</i>	( " 3)	.. ..	2.19-3.36	3.32-3.39
<i>M. orbicularis</i>	( " 3)	.. ..	3.51-3.64	3.67-3.76
<i>M. minima</i>	( " 3)	.. ..	2.92-3.07	3.20-3.22
<i>Trifolium subterraneum</i>	( " 1)	.. ..	3.23-3.38	3.23-3.28
" "	( " 2)	.. ..	3.21-3.21	3.17-3.17
" "	( " 4)	.. ..	3.12-3.38	3.26-3.77
<i>T. pratense</i>	( " 3)	.. ..	3.11-3.43	3.67-3.80

The nitrogen content is thus upon the whole somewhat lower at acid reaction, but this effect is neither constant nor very marked, such as found by Virtanen (1928) in peas and clovers grown in artificially acidified sand.

#### DISCUSSION.

A striking feature of the preceding experimental results is the remarkable difference shown to exist between *Medicago* and *Trifolium* in respect of tolerance towards acid soil reaction. When adequate supply of calcium and phosphate is provided, the net gain of nitrogen by subterranean clover in soil as acid as pH 5 does not seem to be improved by liming to pH 7.0-7.5, or the gain may actually decrease owing to stronger utilization of soil nitrogen. Lucerne also continues to fix nitrogen at pH 5 and less, but the gain is strongly increased by liming, although the results in Table 1 suggest that considerable latitude exists and that at least a moderately acid reaction is not harmful.

The commonly held view that symbiotic nitrogen fixation proceeds most vigorously at approximately neutral soil reaction thus seems to hold fairly well for *Medicago*, but not for *Trifolium*. Such a difference was also observed in earlier experiments by Fred and Graul (1916), who grew leguminous plants in two acid soils (pH not determined), with and without inoculation of the seed with nodule bacteria and with addition of calcium carbonate to half and full saturation of the lime requirement as determined by the method of Veitch (titration with lime water). Lucerne and red clover showed in the inoculated series the following net gains of nitrogen in mgm. per pot:

Plant.	Lime Addition.	Soil No. 1. (0.198% N).	Soil No. 2. (0.09% N).
Lucerne .. ..	None.	2,293	497
" .. ..	Half dose.	1,929	2,792
" .. ..	Full dose.	2,127	2,081
Clover .. ..	None.	2,306	3,916
" .. ..	Half dose.	2,514	4,217
" .. ..	Full dose.	2,179	4,213

It is further seen that in Experiments Nos. 1-3, which represent soils of normal although rather low nitrogen content, the final quantity of nitrogen in soil plus plant roots is frequently less than the initial nitrogen content of soil plus seed, as also found by Fred and Graul (1916), but in Experiment No. 4 the nitrogen in the root systems alone represents a considerable gain to the soil originally very poor in nitrogen. This also agrees with the results of Bjälfve (1935) who found that a pea crop assimilated

large amounts of combined nitrogen from a fertile loam soil with 0.132% nitrogen, whereas a vetch crop increased the nitrogen content of a sand soil comparable to the one used in the present Experiment No. 4 (N-content originally 81.0 p.p.m., after vetches 101.5 p.p.m.). Soils of such low nitrogen content are not likely to be met with in normal agricultural practice, but such cases might be represented by land denuded through soil erosion. If a stand of legumes were established under such conditions, we might expect considerable benefits to the nitrogen content of the exhausted soil even if all top material were removed by cropping or grazing, a rule which does not necessarily apply to soils with a more normal nitrogen supply.

#### SUMMARY.

Species of *Medicago* and *Trifolium*, chiefly lucerne and subterranean clover, were grown under greenhouse conditions in soils of pH 4.6 to 5.4, in which the reaction was altered to neutral or faintly alkaline by addition of calcium carbonate.

Determination of nitrogen in seed and crop, and in soil before and after plant growth, showed a marked difference between the two genera. Lucerne fixed at pH 7.0-7.3 roughly twice as much nitrogen as at pH 4.9-5.2; in one experiment there was no significant difference in gains of nitrogen at pH 5.3-5.5 and pH 7.6. *Medicago tribuloides* and *M. orbicularis* were strongly inhibited at acid reaction, but could still fix small amounts of nitrogen at pH 4.6-5.1. Subterranean clover on the other hand fixed the same amount of nitrogen in acid and neutral to alkaline soil, or the net gain was actually smaller in the latter case, when the plants derived a higher proportion of their nitrogen from the soil. Nitrogen fixation in red clover seemed in a single test to be actually favoured by acid soil reaction.

The uptake of combined nitrogen from soil of moderate nitrogen content (0.048-0.077%) was increased by the addition of lime which stimulated the production of nitrate from the soil humus. Only one experiment with subterranean clover in soil of extremely low nitrogen content (0.012%) showed some evidence, but not convincingly, that some combined nitrogen had been excreted by the root systems.

A control experiment with soil carrying wheat plants showed no evidence of non-symbiotic nitrogen fixation, but on the contrary a small net loss of nitrogen.

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NOTES ON THE GEOLOGY, PHYSIOGRAPHY AND GLACIOLOGY OF THE  
KOSCIUSKO AREA AND THE COUNTRY NORTH OF IT.

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(Plates ix-x; Four Text-figures and one Map.)

[Read 29th November, 1944.]

INTRODUCTION.

The following notes embody the results of observations made by us in the course of a short reconnaissance trip last January, and by one of us during previous short visits, to the Kosciusko area. The principal purpose of the latest trip was to examine the country north of the Snowy (referred to below as the northern area), and in particular, to search for traces of the Pleistocene glaciation in continuation of those already described from the Kosciusko block. For comparative purposes we spent a few days in the latter area examining the glacial evidences, and we were able to note a few features not previously recorded; thereafter we went north, crossed the Eucumbene at Eastbourne and spent a week in the Main Divide country, making our headquarters at the Alpine Hut. The relation of the two areas is shown on the map. Time did not permit us to make an intensive study of any problem, or to link up the physical features of the Kosciusko and northern areas by continuous survey, but we were able to satisfy ourselves that relics of the Pleistocene ice-age are to be found as far as a point on the Main Divide 13 miles north of the latitude of the Kosciusko Hotel, which was the northern limit of our investigations.

The present account can in no way be regarded as final or complete, and many of our interpretations are necessarily tentative and subject to modification; nevertheless we have felt that a useful purpose might be served by placing our notes on record for the benefit of future investigators.

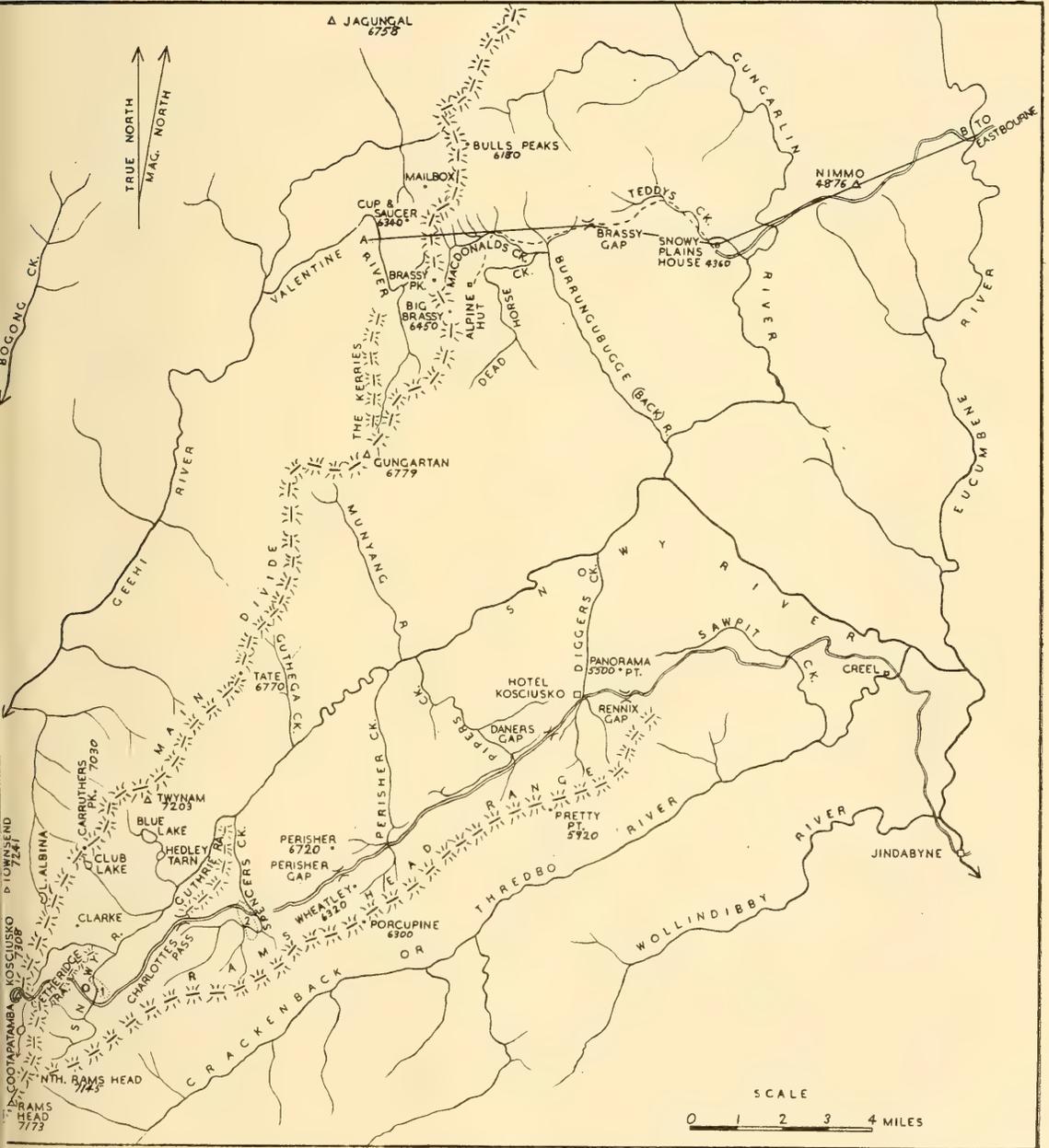
We gratefully acknowledge a grant for expenses from the Commonwealth Science Research Fund administered by the University of Sydney.

GEOLOGY.

Though a specific study of the rocks of the areas visited was not made, it became clear to us that elucidation of the problems of physiography and glaciology will depend in some degree on a knowledge of the geological formations; hence a brief account of our observations will not be out of place.

Nearly all of the country visited is composed of granite, of which two separate intrusions are recognized, apparently of different geological ages. First, and by far the more extensive, is the Berridale batholith, first encountered along the Berridale road eight miles out of Cooma; with but little interruption it continues west across the Snowy Valley to the Kosciusko block, where it extends to Mt. Twynam, the Blue Lake and the Etheridge Range. From Berridale it passes south well beyond Dalgety and north for many miles towards Adaminaby, and in the northern area it extends west at least as far as the ridge known as the Kerries and north beyond the furthest extremity of the area visited by us. From place to place the granite exhibits variations of structure, texture and composition. For the most part it is massive and fairly coarse-grained, but in the broad valley of the Snowy, near Jindabyne, it is notably finer and less acid, and weathers into smaller joint-blocks. Small outcrops of acid phases—chiefly aplite and alaskite—have been noticed in a few places, and particularly in the northern area. As one ascends the Kosciusko road from the Thredbo River the granite is observed to

acquire a rude gneissic structure which becomes very pronounced towards the western margin, where also occasional zones of intense shear may be seen. These features are well shown between the Snowy River and Blue Lake, and they are also very marked in the northern area between Gungartan and Jagungal Peaks. In places the granite contains an abundance of dark xenoliths, which in the gneissic phases become regular *schlieren*. These resist disintegration more strongly than their granite host, and are quite conspicuous among the products of weathering and erosion.



Map 1.—Locality map of the Kosciusko block and the country north of it.  
 (1 = Masson Moraine; 2 = David Moraine.)

Associated with the granite are co-magmatic minor intrusions of fine-grained diorite, hornblende-lamprophyre and hornblende-porphyrite; these are to be seen both in the Kosciusko block and in the northern area.

The second main intrusion is of well-foliated granite-gneiss, typically developed on Mt. Kosciusko; apart from its appearance between Lake Cootapatamba and Lake Albina, it does not come into the region of the present survey. This gneiss is thought to be of *epi-Silurian* age, while the *Berridale* granite may be *Devonian* or *Carboniferous*.

Small dykes of basalt are not infrequent in the neighbourhood of Kosciusko, and of particular interest is the dyke of nepheline-tinguaitite below the moraine-dam of Hedley Tarn, first noted by David, Helms and Pittman (1901).

The only other rocks of the area are slates, phyllites, quartzites and quartz-schists. Upper Ordovician graptolites have been found in the black slates in various places near *Berridale*, and it is probable that all the metasediments are Ordovician. They form scattered outcrops of some size, most of which appear to be roof-remnants to the granite intrusions. One large mass, however, is about seven miles wide on the *Dalgety-Jindabyne* road near *Beloka*, and extends through a vertical distance of at least 1,200 feet; it continues to the north making a prominent ridge, and is about four miles wide where crossed by the *Berridale-Jindabyne* road, but tapers out and disappears a few miles farther north. This may be a gigantic inclusion in the *Berridale* granite or perhaps a kind of screen separating two separate intrusions of magma.

Probably of similar kind is the belt of sediments three or four miles wide traversed by the road from *Eastbourne* to *Snowy Plains House* (*Naphthali's Hut*) on the right bank of the *Eucumbene* River. Much of this belt is composed of quartzite, which forms the high and rough ground rising on the road to 1,200 feet above the river and is probably responsible for *Mt. Nimmo* (4,876 ft.\*). The meridional extent of this mass is not known.

Near *Mt. Kosciusko*, at *Lake Cootapatamba* and *Rawson Pass*, the older and newer granites are separated by a narrow tongue of phyllite and quartz-schist which widens considerably to the north, where it forms *Mt. Clarke*, *Carruthers Peak* and other eminences, as well as some of the lower ground east of the *Main Divide*. This belt, if it persists, must pass west of the country examined by us in the northern area; the smooth profiles of some of the hills west of *Gungartan Peak* suggest that they may be phyllitic.

A word should be said about the prevalence of jointing in the granite on the high plateau, which has been brought into much prominence by frost-weathering. Vertical jointing with submeridional and east-west trends is conspicuous, and subhorizontal joint-planes are very common. There is evidence, particularly at *Lake Albina* and the *Blue Lake*, that these last influenced to some extent the erosion of rock-material by the *Pleistocene* glaciers.

#### PHYSIOGRAPHY.

##### *Kosciusko Area.*

The high plateau trending north and south through *Mt. Kosciusko*, and containing the *Main Divide* of eastern Australia which separates the *Snowy* and *Murray* River-systems, is part of the early *Miocene* peneplain which has been raised to its present elevation by a series of movements culminating in the late *Pliocene* *Kosciusko* uplift (*Andrews*, 1910), and from many points of vantage the appearance of the plateau is seen to be that of an uplifted peneplain, albeit much modified by dissection.

The broad, trough-like valley of the *Snowy River* above *Jindabyne*, and its continuation to the south as an undulating lowland traversed by the *Mowamba* and other *Snowy* tributaries, have been considered to form a fault-trough or sunkland bounded east and west by the horsts of *Barney's Ridge* and the *Kosciusko* block respectively (*David*, 1908; *Sussmilch*, 1909). The discussion of these matters is beyond the scope of the present

\* Heights marked on the map have been taken from the Map of the Snow Leases in the Shires of *Snowy River* and *Tumbarumba*, published by the *New South Wales* Department of Lands in 1943. Other heights given in the text are from our own aneroid readings and are only approximate.

paper, but it may be noted first, that the granite of the broad valley is finer-grained, less acid, more closely jointed and more easily weathered and eroded than that of the higher ground to east and west, and in the second place that the valley walls close in to the north above the confluence of the Thredbo, Snowy and Eucumbene Rivers. There is a suggestion, therefore, that the local widening of the valley is a function of rock-composition and structure and of the increased volume of water available for the work of erosion. But while considerable doubt exists as to the tectonic origin of the Snowy Valley, there are some reasons for believing that the Kosciusko block is bounded on the east by faults. Observations made during the recent trip and on previous occasions suggest most strongly that the plateau descends to the Snowy Valley by a series of giant steps or terraces. From Jindabyne the lower ones are scarcely discernible owing to their dissection by the Thredbo River and Wollondibby Creek which flow obliquely across them. On the ascent by road from the Thredbo River, however, a number of steps is crossed, indicated by relatively level stretches of road and in some instances by the presence of swampy flats (Fig. 1). The first terrace is reached less than a mile past the Thredbo Bridge at a height of about 3,200 feet; this appears to be equivalent to the upper floor

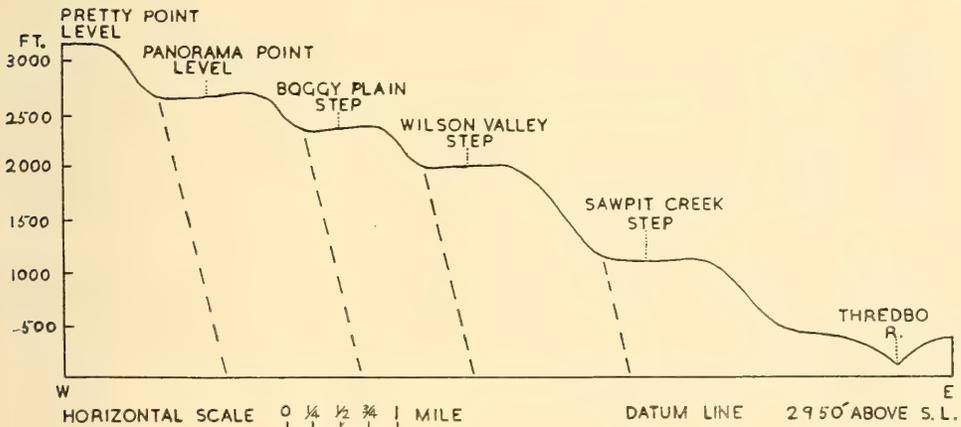


Fig. 1.—Sketch-section across the Kosciusko scarp from the Thredbo River bridge westward. (Broken lines represent hypothetical faults.)

of the broad valley in which the Snowy and Thredbo are incised. A second step, whose existence was recognized by David (1908), is seen near where the road crosses Sawpit Creek at about 4,000 feet; another is at Wilson's Valley (4,850 ft.) and yet another at Boggy Plain (5,200 ft.). This last is particularly well seen on both sides of the road below Rennix's Gap, and the photograph (Plate ix, fig. 1), taken in 1922 from a point some distance south of the road looking north or north-east, gives a clear impression of the step from its western boundary to the edge where it descends to the next step. Like some of the others, this terrace has a slight tilt to the west.

Above Boggy Plain the ground rises to 5,500 feet at Alpine View and Panorama Point, so that from the Thredbo Bridge there is a rise of nearly 2,550 feet in a horizontal distance of six miles. This does not mark the upper limit of terracing (though it is no longer perceptible from the road), for in 1908 David suggested that a fault with a throw to the east of about 200 feet passed just east of Pretty Point in a general northerly direction along Digger's Creek, and from an inspection of the map recently issued by the Department of Lands it would certainly appear that greater elevations are attained on the west than on the east of Digger's Creek, though dissection of the *terrain* prevents the eye from appreciating this fact from most aspects. The Pretty Point terrace, between 5,900 and 6,000 feet high and about five miles wide, probably constitutes the most extensive surface on the Kosciusko block, and it is the level which forms the sky-line of the plateau when viewed from Jindabyne.

A marked increase in the elevation occurs west of the line of Perisher Creek, strikingly brought out in the form-line map in the paper by Taylor, Browne and Jardine (1925). The summit-levels in this much-dissected area are all well above 6,000 feet, and include The Perisher (6,720 ft.) and Paralyzer, Mt. Twynam (7,203 ft.), Carruthers Peak (7,030 ft.), the ridge running north-east from Ram's Head to the Porcupines separating the Snowy and Crackenback (Thredbo) Rivers, and the culminating eminences of Mt. Townsend (7,241 ft.) and Mt. Kosciusko (7,308 ft.). From the neighbourhood of Pretty Point it is possible to look west across the Pretty Point surface and observe in the distance the higher levels rising above it; conversely a view to the north and north-west from some of the higher points in the Perisher group reveals the peneplain surface of the Pretty Point terrace at a lower level, furrowed by the Snowy River and its tributaries. From points of vantage east and south-east of Jindabyne it is possible to trace the terrace far to the south, with the higher points of the Kosciusko-Perisher surface rising in the distance above it.

Detailed work might well reveal the existence of other terraces in addition to those enumerated; in this connection a series of aerial photographs would be of the greatest value.

The first explanation of the terrace-topography that presents itself is, of course, step-faulting to the east. Since the *terrain* is almost exclusively granitic, the influence of differential hardness cannot come into play on the large scale, and neither the gneissic foliation nor the prevalent jointing can account for the major topographic features. Moreover, the Snowy and Thredbo Rivers and their tributaries show marked valley-in-valley structure. It is difficult, therefore, to escape the conclusion that the present topography has resulted primarily from faulting of a peneplain during its elevation into a plateau, though the highest elevations may be residuals from an older erosion surface.

*Northern Area* (see Fig. 2).

Crossing the bridge (3,540 ft.) over the Eucumbene near Eastbourne, where the river has cut its bed some 500 feet below the general plateau-level, the road to Snowy Plains rises 1,200 feet in three miles to cross the Mt. Nimmo ridge. In another mile it

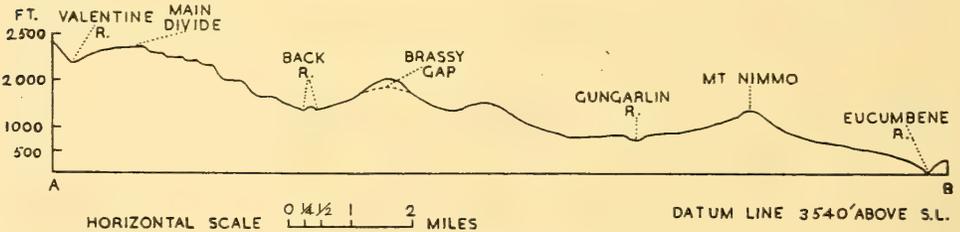


Fig. 2.—Generalized sketch-section across the northern area along the line AB on the map. (Broken lines represent hypothetical faults.)

has reached the edge of the wide, undulating treeless plain forming the valley of Gungarlin River. From Snowy Plains House (4,360 ft.) the track to Alpine Hut rises some 270 feet in two miles along Teddy's Creek, and half a mile farther on, leaves the creek on the right and ascends along the south side of its valley to Brassy Gap (5,375 ft.), a flattish col or saddle some 800 yards wide in a ridge which rises perhaps 200 feet on either side and forms the watershed between the Gungarlin River and its tributary the Burrungubugge or Back River. At the point where the track leaves Teddy's Creek there appears to be a terrace at 4,900 feet, but no other suggestion of terracing has been observed between Gungarlin River and the Brassy Gap ridge, though it should be noted that this is about 400 feet higher than the Mt. Nimmo ridge.

From Brassy Gap a distant view to the west may be obtained of a series of terraces which descends from the Main Divide (6,200 ft.) towards the Back River (4,950 ft.) and is partially dissected by Macdonald's Creek and other creeks. The lowest terrace is at 5,280 feet, and at 5,500 feet is another, on which Alpine Hut is situated. This is backed

by a rather steep scarp 400 feet high and is succeeded by a flight of smaller steps extending back to the Main Divide.

The Main Divide in this area runs in a general north-north-east direction and varies in height from 6,000 to nearly 6,800 feet, but it includes by no means all of the highest land. Thus it passes through Gungartan (6,779 ft.), but leaves other high points such as Cup and Saucer Hill (6,340 ft.) and Jagungal (6,758 ft.) on the west. The last of these towers above the general level of the plateau and has all the appearance of a monadnock, but though Gungartan may also be one, it does not stand out so prominently. The dominating land hereabouts is the ridge known as the Kerries, running north from Gungartan for three miles with gradually diminishing elevation. Its eastern side forms the steep western wall of the somewhat asymmetrical valley of Valentine River.

It was not possible in the time available to explore the details of the terracing in the neighbourhood of the Main Divide, but we had the opportunity of making some reconnaissance observations. Viewed from the top of the hill known as the Big Brassy (6,450 ft.), itself possibly a pre-Miocene residual, the terrace-topography stands out with diagrammatic clearness, and one gets the impression that many of the steps have a gentle tilt to the west, which has induced the formation of shallow lakes or swamps or of longitudinal streams and streamlets. To the south and south-west of Big Brassy one observes the tread of a broad step, or perhaps two shallow steps each about half a mile wide, tilted gently to the west and extending from the foot of the Kerries east to the Main Divide, where there is a drop to the east. This step continues for about two miles north of Big Brassy, and though beyond the hill known as the Mailbox it is not so evident, yet the very gentle western slope from the Main Divide is in sharp contrast to the abrupt eastward drop.

Immediately north and north-north-west of Big Brassy, where for a couple of miles the Main Divide is offset to the west, the step-topography is particularly well exhibited. Not all the scarps which bound the terraces are parallel; some of them converge to form wedge-shaped blocks. Big Brassy itself seems to slope directly down to the Alpine Hut step, but the Divide north from Brassy Peak (6,300 feet) is separated from the lower level by another terrace at 5,900 feet which can be followed by the eye for about two and a half miles to the north. The Alpine Hut step (5,500 ft.) is even more prominent, and can be traced clearly from some distance south of Big Brassy for perhaps three miles, to a point north of Macdonald's Creek. Its eastern edge, where it descends to the 5,280-foot terrace, is well defined. Nearer the Divide, to the north of Macdonald's Creek, a flight of smaller terraces can just be discerned; these have been glaciated and are described in some detail below.

To account for the terracing in this northern area as in the Kosciusko block one is tempted to postulate step-faulting, and certainly the major topographic features from the Kerries almost to the Back River are in harmony with such a hypothesis. East of this there are few, if any, indications of terracing, and the profiles suggest rather an upwarping of a maturely dissected surface. It is possible, of course, that original terracing has been obliterated by erosion.

If meridional faulting was really responsible for the terraces, one might expect to find some signs of dislocation on the western margins of the steps. At a few points we did indeed observe in the granite unusually close-spaced vertical jointing with sub-meridional trend, but no definite evidences of faulting were seen. In future field-work the search for such indications should be regarded as a matter of prime importance.

No definite linking up of any of the northern terraces with those of the Kosciusko area has been effected, but it may be significant that the course of Valentine River which bounds the highest land in the area is collinear with that of Perisher Creek, the eastern boundary of the Perisher block.

#### RIVERS AND LAKES.

In the region under consideration, two main trends of stream-flow are manifest. First is the north-east direction which is followed by the Upper Snowy, Thredbo, Wollondibby and Mowamba, and which is also seen in those tributaries of the Upper Snowy whose valleys are traversed for many miles by the Kosciusko road from the hotel to the

summit. The streams following this direction cut obliquely across the terraces of the plateau. The other trend, which is submeridional, is well seen in the Snowy above Jindabyne, the Eucumbene, the Gungarlin and a multitude of minor tributaries such as Spencer's, Guthega, Munyang, Perisher, Farm and Digger's Creeks in the Kosciusko block and the Valentine River and Dead Horse Creek in the northern area. The conflict of these two trends has resulted in many boat-hook bends or barbed junctions.

We are unable to offer any general explanation for these peculiarities, which appear to be related to some major regional influence, perhaps of a tectonic nature.\* Some of the submeridional streams may be connected with faulting or terrace-formation.

The rivers of the Kosciusko block, especially the Snowy and Thredbo, show clear evidences of rejuvenation, and the Snowy exhibits repeated valley-in-valley structure where it emerges from the highlands (Plate ix, fig. 2). Between this point and Jindabyne it flows some 300 feet below the high floor of its broad valley, and 80 or 100 feet below the top of a shingle terrace. That some at least of the entrenchment followed the recession of the Pleistocene glaciers is indicated by valley-in-valley structure on Digger's Creek below the hotel and on the Snowy at Charlotte's Pass, where it is almost at the head of rejuvenation and an old glacial lake has been drained. The evidences of glacial scour of the valleys and of the formation of temporary lakes are considered below.

An interesting example of the relation of erosion to geological structure is to be seen on the highest part of the plateau. Between the older granite-gneiss of the Kosciusko summit and the newer granite lying to the east is a wedge-shaped mass of phyllite which, like the Kosciusko granite-gneiss, has a general easterly dip. Erosion has been to a large extent guided by the phyllite-gneiss junction, and accordingly we find that Lake Cootapatamba and the stream draining it, the col known as Rawson Pass, one of the headwater tributaries of the Snowy, Townsend Pass and the Lake Albina Valley are all aligned on this geological boundary.

In the northern area we note that at Snowy Plains House the Gungarlin is meandering in a wide grassy valley some 30 feet below an alluvial terrace. Here it is flowing roughly south and parallel to the Eucumbene but at 800 feet above it. Lower down its valley becomes deeper and steeper and we understand that at its junction with the Snowy it has cut a precipitous gorge some 1,350 feet deep. From Snowy Plains to its mouth, the river falls some 560 feet in about nine and a quarter miles, and it is flowing against the slope of the plateau-surface. The Back River, where the Alpine Hut track crosses it, is about 550 feet above the Gungarlin and in a much less mature valley; it, too, becomes deeply entrenched before its junction with the Gungarlin. It appeared to us that these rejuvenated streams, as well as the Snowy and Thredbo, must date back to a time anteceding the final uplift of the plateau at the close of Pliocene time.

Some interesting details of drainage are to be seen in the neighbourhood of the Main Divide. The longitudinal course of the Valentine River appears to have been influenced by the tilted terrace lying just east of the Kerries. Macdonald's Creek, a consequent tributary of the Back River, has cut its way through a series of terraces near the Divide, and is joined by a number of tributaries draining them longitudinally. Dead Horse Creek east of Big Brassy is a longitudinal stream, which flows north along the Alpine Hut terrace for some distance and then turns sharply to the east and descends rapidly towards the south-flowing Back River. A col separates it from Macdonald's Creek, and the indications suggest that it formerly joined the latter and was subsequently captured through headward erosion by another tributary of Macdonald's Creek.

It is noteworthy that the valleys on the higher parts of the plateau are mature to old, and that many of the streams meander about, sometimes in rather swampy ground (Plate x, fig. 1), very much as in the Kosciusko area.

#### GLACIAL EVIDENCES.

##### *Kosciusko Area.*

In his 1908 paper, David pointed out that the Kosciusko area had experienced two phases of Pleistocene glaciation, the first and more extensive an ice-cap glaciation; the

\* David (1908) suggested faulting along the valley of the Thredbo River.

second expressed in valley-glaciers. He enumerated and described several of the manifestations of both phases and his observations were added to by the work of Taylor, Browne and Jardine. The following notes may be regarded as supplementing and amplifying the work of previous observers.

According to David, the ice-sheets of the earlier glaciation overrode the existing topographic features, crossing the Snowy River and mounting the ridges to the east. On this and a previous excursion new evidences as to the route taken by the ice were seen. Reference has been made to a dyke of nepheline-tinguaitite about half a mile below Hedley Tarn. This rare rock-type, easily recognizable in hand-specimen, has not been discovered elsewhere *in situ* in the area, but erratics of it have been found one mile south-south-east of the dyke on top of the Guthrie Range, as well as in the David moraine in Spencer's Creek. There can be little doubt, therefore, of the direction from which the ice was moving, and significant in regard to the thickness of the ice-sheet is the fact that the blocks picked up from the dyke must have been carried down to about 5,500 feet and then raised through a vertical distance of more than 600 feet to be deposited on the Guthrie Range.

Another piece of evidence suggesting that the ice-sheet crossed the Snowy was provided by the finding of glacially-striated stones of quartzitic phyllite near Charlotte's Pass on the right or eastern bank of the river and at heights of 130 and 140 feet respectively above it. Actually it would appear that much of the slope forming the eastern side of the Snowy Valley from the Masson moraine to Charlotte's Pass is covered with a veneer of ice-borne boulders, mostly of granite but including also quartzite and phyllite, embedded in a somewhat gritty matrix. Where this matrix has been locally washed away by snow-fed streamlets the boulders are thrown together with open spaces between. The above description applies equally to much of the country bordering the road on the east as far down as Rennix's Gap, and the suggestion may be made that the boulders really form a kind of ground-moraine left behind by ice-sheets which came from the high land immediately to the west and north. Many of these eastern (or west-facing) slopes are much more gentle than those on the west, and their profiles are very suggestive of *roches moutonnées*. A good example is afforded by Mt. Wheatley, south of the Perisher Gap, as viewed from the north-east (Plate x, fig. 2). Similar profiles are exhibited at intervals along the Snowy-Thredbo divide between the Porcupines and Pretty Point. No smoothed rock-surfaces have been observed on the gentle slopes, partly because of the covering of ice-borne boulders, partly also, no doubt, on account of post-glacial weathering and erosion.

It would appear that, as suggested by David, the ice-sheets originating in the high country between Mts. Kosciusko and Twynam crossed the Snowy, mounted the slope of the Ramshead Range and spilled over into the Thredbo Valley partly through the boulder-strewn marshy flats or cols which are so characteristic of the Ramshead Range. To do this, part of the ice-sheet had to mount the Guthrie Range and cross the valley of Upper Spencer's Creek. When the ice-sheet dwindled and lost thickness its course was directed by the valleys it had crossed; thus one part passed down the valley of Spencer's Creek wherein it deposited the David moraine, while another branch made its way down the Snowy Valley from its head. This glacier must have been of considerable size and power, to judge from the truncated spurs (Plate x, fig. 3) which are to be seen when one looks downstream from the neighbourhood of Charlotte's Pass. How far it went down the river has not been determined, but it eventually shrank back to a point near the road-crossing, where it deposited the Masson moraine.

From the neighbourhood of the Perisher and other gathering-grounds to the north-east, the ice-sheets moved south or south-east, crossed the valleys in which the road runs, and made their way up the opposite slopes and over into the Thredbo. At a later stage the shrunken glaciers moved down the headwater valleys of Perisher, Piper's and other creeks parallel to the road and then turned north along the main creeks towards the Snowy. The lowest and most northerly of these valleys is that in which is situated the golf-course of the Kosciusko Hotel at a height of 5,000 feet; so far as we know this marks the lower limit reached by the ice in the Kosciusko area, though it may have continued down the valley of Digger's Creek below the hotel.

The passage of glacier-ice down these valleys is indicated by their typical U-shaped cross-sections and flat floors, by the presence of small *roches moutonnées* in Perisher Creek and a small moraine in the golf-course creek, and by the fact that not infrequently the heads of the creeks are found to occupy little hanging valleys. Near the road, at two miles past the hotel, one may see where the Piper's Creek glacier cascaded over a rock-barrier, now breached by post-glacial erosion.

The wide and definite cols—Daner's, Piper's and Perisher Gaps—over which the road runs were in the first instance the result of erosion by collinear creeks, but they were later widened by the passage of ice, and subsequently, on the dwindling of the ice-sheets, functioned as ice-partings.

The relics of the second or minor glaciation are seen chiefly in lakes like Cootapatamba, Albina, Club Lake, Blue Lake and Hedley Tarn, and in cirques and drained lakes with moraine-dams. Most of these have been described already, and we have made only a few supplementary observations.

Descending from Rawson Pass (6,930 ft.) along the valley to the south-south-west, we meet first the moraine-dammed Lake Cootapatamba at about 6,740 feet. Beyond this, and at 90 feet below it, a drained lake is enclosed by another moraine, and further down, the creek flows through what has been a more extensive lake, whose rather coarse and gritty sediments are seen in the creek banks at between 6,340 and 6,315 feet. The lake was evidently very shallow, for the creek is in many places flowing over bedrock. From a distance it seems as if the lake had been bounded by a low rock-barrier, but the creek turns sharply west and flows through a little rocky gorge it has cut for itself, while the broad flat plain continues to the south-south-west and ends rather abruptly on the edge of a youthful post-glacial valley. This shallow rock-basin may mark the farthest limit reached by the Cootapatamba valley-glacier.

North-north-west of the Blue Lake, and perched some 250 feet above it, a well-defined little cirque was noted, with walls extending up perhaps a further 200 or 300 feet (Plate x, fig. 4). The breaching of a low bank of moraine has drained the shallow lake formerly impounded on the granite floor of the cirque. The back or western wall is of phyllite, and some fine examples of large perched blocks of phyllite resting on granite are to be seen (Plate x, fig. 5). The water from the cirque drains down a steep little boulder-strewn valley west of the Blue Lake before entering it. On the northern side of the cirque and some 40 or 50 feet above it, another smaller cirque was seen; this was partially filled with snow, and it would be hard to say how far its excavation was Pleistocene and how far it is the result of present-day nivation.

By far the most impressive cirque in the Kosciusko area is an unnamed one lying close under the Main Divide just north of Mt. Clarke and deeply incised behind it. It is the best part of half a mile in diameter, with walls perhaps 400 feet high. It does not contain a lake, though its exit is partly blocked by moraine. A projecting spur separates it from the cirque—smaller but still impressive—containing the Club Lake.

The lowest cirque we observed is that on the eastern slope of the Perisher near the road. Its floor is about 5,800 feet above sea-level, and it hangs above the valley of Perisher Creek. It possibly belongs to the waning phase of the earlier glaciation.

#### *Northern Area.*

This area, too, we consider, exhibits relics of both the earlier and the later Pleistocene glaciation, though these are by no means so striking and convincing as at Kosciusko. For the ice-cap phase the chief gathering-ground appears to have been the Kerries ridge, and since we have not examined its western side we can speak only of the east. Ice-sheets appear to have moved eastward and in a general way downward, passing over the Main Divide. No definite indications of mass-movements of ice have been observed below 5,800 feet, though lobes or tongues descended to lower levels. The ice, of considerable but unknown thickness, cascaded over the scarps of the topographical terraces, by this time somewhat dissected, and modified their profiles.

The chief glacial evidences are *roches moutonnées*, boulder-strewn flats or cols, ground-moraine and terminal moraines.

Among the striking topographic features of the area are the asymmetrical hills and ridges with gentle slope to the west and steep faces to the east, which, like their counterparts in the Kosciusko area, convey more than a suggestion of glacial abrasion, even though their configuration may have been in the first instance imparted by step-faulting. Examples on a large scale are seen south and west of Brassy Peak between Valentine River and the Main Divide (Plate ix, fig. 3); another example is afforded by the ridge culminating in Brassy Peak, with its bare rocky slopes that seem to have been smoothed by ice and modified by exfoliation (Plate ix, fig. 4). Big Brassy itself, towering to 6,450 feet, is the greatest of them all. In addition there are, particularly in the country immediately north of Big Brassy, numbers of low, rounded hillocks of granite which, though less striking, are apparently also *roches moutonneés*. It is true that for the most part the smooth-seeming curved profiles of the ridges are found on close inspection to be roughened and boulder-strewn, but this may well be the result of post-glacial weathering.

Numerous flats or cols, exactly similar to those in the Kosciusko area by which tongues of the ice-sheets made their way into the Thredbo Valley, have been observed down to a level of about 5,450 feet. One of the largest is that on the Main Divide, separating Brassy Peak and Big Brassy at a height of 6,160 feet. Doubtless these depressions were originally water-made and were widened and flattened by the passage of the ice. One col trending east-west on the gentle western slope from the Main Divide, near Bull's Peaks, is cut in phyllite, apparently a great inclusion in the granite, but, contrary to expectation, it contains no granite boulders, and their absence is hard to explain. Evidently there is room for further investigation into the origin of these cols.

The flat valley about a quarter of a mile wide, by which the track ascends from Back River to Brassy Gap, is for the most part treeless and grassy and in places boggy, but along the creek that flows down one side there are in places great masses of granite boulders piled tumultuously with no trace of solid rock to be seen. The arrangement suggests glacial deposition, but further examination is necessary. It appeared to us that Brassy Gap and a similar col in the same ridge might possibly have provided outlets for lobes of an original thick ice-sheet moving eastward from the Kerries to the Main Divide and across the Back River. If this suggestion be correct there should be some traces of morainic material on the eastern fall of Brassy Gap along Teddy's Creek. This is relatively steep and thickly forested and we did not examine it. It is possible that, as at Kosciusko, the ice-sheet in its waning stages broke up into small glaciers which moved along the longitudinal river-valleys. The valley of Valentine River bears some suggestion of glacial erosion, as do the headwater tributaries of Macdonald's Creek, particularly that running north from Big Brassy. The glacier in this valley may have had an outlet to the Alpine Hut terrace immediately north-west of the hut, where there is in the scarp a recess partly filled with moraine.

Another noteworthy feature of this northern area, particularly at the higher levels where vegetation is scanty, is the profusion of granite boulders strewn over the cols, and indeed over the surface generally, though not with the prodigality characteristic of the Kosciusko area. Some of these boulders are manifestly the result of weathering *in situ*, but a large proportion should probably be regarded as ground-moraine. Distinction between joint-blocks and erratics is in general difficult, except where acid phases of the granite exist. On the east and north-east of the Mailbox Hill, for instance, alaskite forms small but conspicuous outcrops, and large boulders of this rock were found half a mile away to the east and uphill from the outcrops, indicating glacial transport. It seems possible that careful mapping of the sparsely-distributed variants of the granite may enable estimates to be made of the extent and direction of ice-movement.

An examination of the country near the Main Divide immediately north of Macdonald's Creek heightens the impression of glacial sculpture by ice moving from the west. The Divide, at an elevation of about 6,200 feet, is a rather insignificant feature, with a gentle westerly slope towards Valentine River along a flat and somewhat marshy tributary valley. The small east-facing scarp of the Divide, 150 feet high, is mainly of solid granite, but partly of moraine-material—tumbled boulders in a matrix of granite-grit and soil. Succeeding this to the east are a series of three or four shallow steps

(see Fig. 3) each partly occupied by a swampy flat dotted with granite boulders, and each fronted by a scarp composed partly of masses of smoothed solid granite—evidently *roches moutonnées*—and partly of morainic material (Plate ix, fig. 5). The first two steps are each about one-quarter of a mile broad, and their bounding scarps about 100 or 150 feet high; the third step is much wider and is really double, being crossed about the middle by a small scarp perhaps 50 feet high. On the south, the flat valley of Macdonald's Creek, starting in a col in the Main Divide, collects the drainage from the steps, and on the north, another branch of the same creek flanks the steps, gathering in tributaries from the solid granite country on its left bank. These latter head in cols and are flat and evidently ice-worn; indeed the main creek is barred by two low moraines about 100 or 150 yards across, one at 5,900 and the other at 5,950 feet.

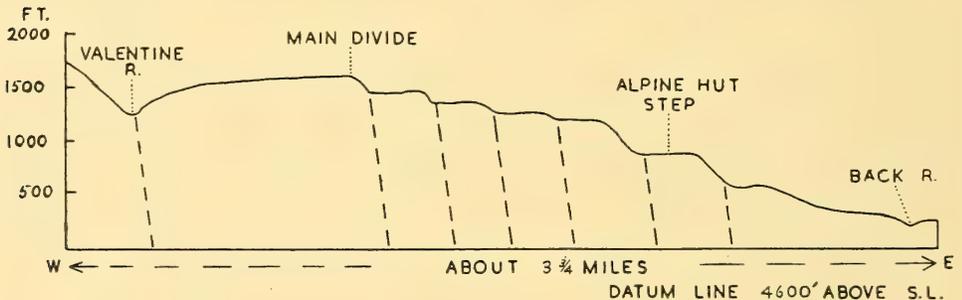


Fig. 3.—Sketch-section across the terraces north of Macdonald's Creek. (Broken lines represent hypothetical faults.)

The third step, with its lowest edge at about 5,800 feet, has a number of flat outlets to the east partly filled with moraine, and it would seem that the ice-sheet gouged these out in its passage over the scarp. There is a steep drop of about 400 feet on to the next level, which is really an eroded northern continuation of the Alpine Hut step. The scarp has suffered a good deal of dissection, and in particular the northern branch of Macdonald's Creek has cut a deep cirque-like recess into it (Plate ix, fig. 6). The course of Macdonald's Creek across the Alpine Hut terrace is marked by a profusion of tumbled boulders, and these become more abundant and conspicuous where the creek flows from the terrace down one side of a flat-floored valley to Back River. The tumbled material, which includes some quartzite as well as granite, and whose boulders may be up to 12 feet in length, extends through a vertical interval of 200 feet to a level of 5,180 feet, which marks the lowest elevation at which we have seen what we consider to be morainic material. From the Main Divide to this point there is a total drop of 1,000 feet in a horizontal distance of two miles.

Though no ice-scratched stones and no striated pavements were found, we feel reasonably sure that the present topography has resulted from the passage of ice over a flight of terraces—perhaps due to step-faulting—that had been modified by river-erosion. We are unable to say whether the ice-sheet in its prime crossed Back River and reached the ridge containing Brassy Gap, but certainly lobes or tongues of ice, perhaps during the waning phase, made their way over the scarp on to Alpine Hut terrace, and one of them followed the valley of Macdonald's Creek down for some distance towards Back River, the valley being choked by moraine on the retreat of the glacier.

It was somewhat surprising to find that moraine-material had survived as scarps to the steps, but doubtless it is preserved from erosion by the adjacent outcrops of solid granite as well as by the covering of snow which lasts for several months of each year.

Gungartan Peak is composed of large joint-blocks of granite, very evidently *in situ*, and we could find no signs of glaciation in its immediate vicinity; possibly it projected as a *nunatak* during the maximum glaciation. The country to the west of it is smoothed as if by glaciers and contains what appear to be small *roches moutonnées*, but we had not time to examine the area east, west or south of the peak.

The features tentatively attributed to the later glaciation consist entirely of cirques. Five of these were observed:

- (1). At the head of Valentine River three-quarters of a mile north-north-east of Gungartan Trig. Station at 6,550 feet. A little hanging valley 50 or 60 feet above the main valley-floor, with a wall not more than 50 feet high. A small moraine formerly dammed a lake now drained.
- (2). High up on the left bank of Valentine River three-quarters of a mile above Mawson's Hut, at about 6,130 feet. Observed from the right bank.
- (3). On the eastern slope of the Kerries at about 6,270 feet and at a point whence Big Brassy bears 51°. The walls are not more than 100 feet high and no definite moraine is visible, but the floor may have contained a shallow lake.
- (4). About one and a half miles north-east of Gungartan Peak. A little cirque at 6,300 feet with a wall about 50 feet high in a creek draining to the north-east.
- (5). A little to the south-west of Big Brassy. A drained lake occupies a hollow, really a small cirque, at 6,125 feet.

Our observations on glaciation extended only for a mile north of Bull's Peaks. Quite probably Jagungal (6,758 ft.) or its immediate environs will yield some glacial evidences, but this should mark their northern limit, for the plateau beyond this point seems to be too low to have been under Pleistocene ice.

#### SNOW-PATCH EROSION AND NIVATION.

The time of our trip was particularly favourable for observing snow-patch erosion because there had been heavy snow falls during the previous winter, and, the early summer being cool, snow was preserved to a greater extent than usual. Countless snow-patches lay all along the eastern side of the main ranges from Kosciusko to Jagungal. The patches generally decreased in size and in number in the lower elevations to the north.

Most of the snow-patches in the Kosciusko region were of what may be called the 'transverse' type, the major axis lying transverse to the line of drainage. As the summer progressed the transverse had subdivided to form longitudinal snow-patches, elongated downhill, in those hollows where the snow was thickest.

The primary reason for the formation of transverse snow-patches, which all occur below the crest of east-facing slopes, seems to be that the snow falling on the crest of a ridge is blown clear of the summit by the prevailing westerly and south-westerly winds; it thus comes to rest and accumulates to greatest depth on the sheltered slopes some 50 to 100 feet below. The chief factor in its preservation would appear to be the greater bulk accumulated in such situations compared with surrounding slopes. Thus the slopes can be differentiated on their capacity to collect and retain drifting snow. Those with the greater capacity are subject to different denudational processes from those which lose their snow early. When the snow thaws early in the season, the vegetation grows quickly and forms a protective cover, but when the snow-patch lasts far into the summer the vegetation is killed and the surface is bared. This results in (a) acceleration of the processes of nivation on the slope while snow is present, and (b) acceleration of erosion by rain run-off when the snow disappears.

At the altitudes at which the snow-patches occur, severe frosts occur at night during all times of the year except mid-summer. In addition during the bright winter days a thaw occurs, as is indicated by the waning of the snow-covered areas between each fall of snow.

Undoubtedly, therefore, the process of nivation is active at all times of the year as long as the supply of moisture remains adequate, that is, in those areas where a large volume of snow has accumulated. Alternate melting and freezing shatters the bedrock below the melting snow-patch, and the loosened fragments themselves are broken up, yielding supplies of fine material.

The snow-patches in the whole of the region showed little or no sign of downhill movement, so that apart from gravity all the transport is done by thaw-water. Only one snow-patch, south of Club Lake on a slope of some 30°, was found to have developed a crevasse. Whether this was due to the movement of the mass over the surface of the

ground, or to differential movement or slumping within the mass, could not be determined.

The most extensive transverse snow-patch or drift observed extended in a serpentine form below the crest-line from the summit of Kosciusko almost to Northcote Pass, a distance of one and a half miles. It varied in width from a few yards to about 30 yards. Some of the patches farther north in the vicinity of Blue Lake and Mt. Twynam averaged about 50 yards in width.

The effects of snow-patch erosion were best exemplified in the steep slopes forming the cirque wall of Club Lake. Plate x, fig. 6, shows the conditions existing during late January, 1944. The longitudinal snow-patches are obviously the remains of a continuous transverse snow-patch. The bare slope was being actively eroded by nivation and thaw-water, which, below the snow-patch, issued in well-defined runnels and carried débris forward to build a delta out into Club Lake.

In the northern area, the snow-patches were very much smaller in extent and had obviously been more extensive during the early summer. All that remained in most cases was a patch some 50 yards long and 5 to 10 yards wide. Observations on the slopes on which these occurred are generalized in Fig. 4.

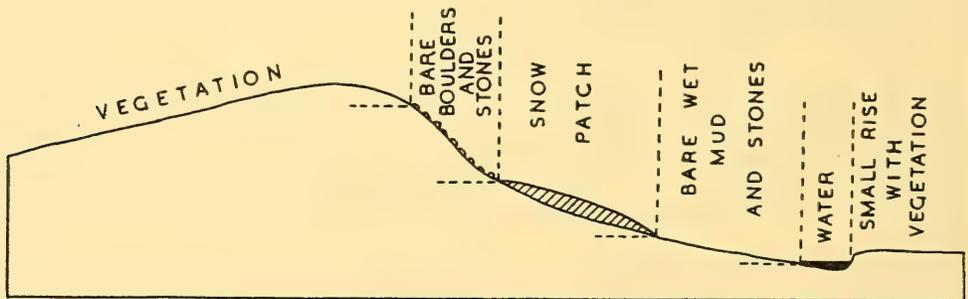


Fig. 4.—Diagrammatic section of a snow-patch and its environment.

The west-facing slope is gentle and at altitudes below 6,000 feet is well covered with vegetation. Below the crest on the east-facing slope, the ground is bare of vegetation and rock-outcrops, boulders, stones and soil are exposed. At the time of our visit, the snow obviously had only recently vacated this area, and the snow-patch, occurring in the lower middle slope, was small in extent. Below it the slope was bare of vegetation, the surface was wet, and over the mud and stones ran streams of thaw-water from the snow-patch. Skirting the foot of the slope is a long shallow hollow in which the thaw-water was dammed. Below it the ground rises six inches to one foot to the level of the gentle slope or flat beyond. This was boggy and covered with coarse grass, low shrubs and some peat.

The whole of the unvegetated zone from the flat to below the crest was probably caused by a snow-patch in the spring and early summer. During the bright summer days, melting proceeded rapidly, runnels flowing from beneath the snow-patch. The flowing water carried with it, from beneath the snow, fine sand and clay particles. Where it flowed over the sodden surface on the slope below the snow-patch, it moved other particles and built up minute cones and deltas in the shallow hollow skirting the foot of the slope. Where clumps of vegetation barred the course of the runnels, small perched vegetation-dams were built up. On those slopes where the snow-patch had just disappeared the bare slope was scoured by small rills showing active denudation, while the foot of the slope was skirted by an apron of fine deposited material.

Evidence would therefore indicate that snow-patch erosion and nivation are playing an active part at the present day in the denudational processes of the plateau. Snow-patches or nivation-hollows recede a little farther into the slopes during those years when abundant supplies of snow are available.

Since the main cirque-glaciers melted at the close of Pleistocene time, these processes must have been active in moulding the landforms and maintaining the steepness of the

slopes. Further work and systematic observation over a period of years are necessary to assess the part played by snow-patch erosion and nivation in the sculpturing of the post-glacial landforms.

#### UPLAND SWAMPS.

The high portions of the Kosciusko plateau are characterized by small areas of upland swamp occurring in country, mainly above 5,000 feet, which is covered with snow from seven to nine months of the year. The swamps tend to develop in places where the drainage is somewhat obstructed by dumps of morainic material, topographic features resulting from glaciation, or hard zones in the granite. They are particularly common in cirques and drained lakes, around moraine dammed and over-deepened lakes, and along the mature floors of the U-shaped valleys above the limits of rejuvenation in the streams draining the plateau (Plate x, fig. 1). The accumulation of organic *débris*, derived from the vigorous growth of the swamp-plants, also tends to hold up the drainage, producing vegetation-dams and promoting swampy conditions. This factor is so pronounced, in some places, that swamps have developed on gently sloping surfaces which, under normal climatic conditions at lower altitudes, would have been drained by their gradient.

Upland swamps were seen round the shores of Lake Cootapatamba and the Blue Lake, in drained-lake areas below Lake Cootapatamba and in Hedley Tarn, in cirques along the eastern side of the Main Range between Kosciusko and Mt. Twynam, along the mature floors of the valleys of the Snowy and its tributaries between Kosciusko and Charlotte's Pass and in Upper Spencer's Creek. They also occur in the northern area, where they were observed in small cirques along the eastern side of the Kerries, on the broad valley-floor at the head of the Valentine River, and on the glaciated steps situated on the eastern side of the Main Divide between Brassy Peak and Bull's Peaks.

The vegetation of the swamps consists of plants resembling peat-mosses, small soft herbage and algal material. These plants grow vigorously during the three or four summer months when the ground is free from snow. Observations suggest that the abundant growth each summer is due to the plants having but three or four months to reach maturity and come to seed, as well as to the fact that the ground is completely saturated with water from melting snow in spring, and remains saturated throughout the summer owing to low rates of evaporation at the high altitudes.

At the end of summer, late in March or in April, snow begins to lie on the ground and covers the summer growth of swamp-vegetation almost before it is completely dead. The low soil-temperatures prevailing in winter and the weight of snow tend to preserve and compress the plant-material into firm but spongy, fibrous beds, which, after burial under additional plant-*débris* during successive summers, become immature peat. The beds are able to withstand to a large extent the flowing water which accompanies the spring thaw, and form a strong foundation for the roots of each summer's growth.

The annual development of swamp-vegetation, under the foregoing conditions, has a profound influence on the drainage and soil-formation along valley-floors and on surfaces of little slope, giving rise to tussocky country and to swampy soils which are remarkably springy underfoot.

The vigorous growth and persistent accumulation of organic material frequently cause the vertical peat-like banks of small streams to unite above the flowing water and form a continuous bed of turf beneath which the streams may flow for considerable distances. Such cases appear to be the reverse of soil erosion, the tendency to accumulation of plant-material overcoming the erosive power of the streams. This results in the building up of peaty beds, but they are only temporary, as the breaching of moraines, the deepening of channels draining lakes and the entrenchment of streams due to rejuvenation, eventually lower the water-table, and the peat is removed during the normal processes of valley development.

#### SUMMARY.

An account is given of observations made on the geology, physiography and glaciology of the Kosciusko plateau and its continuation for some miles to the north.

Step-topography is characteristic, tentatively ascribed to faulting, and traces of the Pleistocene glaciation known to have affected the country around Mt. Kosciusko have been found to extend for several miles to the north.

Observations are recorded on snow-patch erosion and nivation and on the upland swamps so characteristic of the higher parts of the plateau.

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EXPLANATION OF PLATES IX-X.

Plate ix.

Fig. 1.—Boggy Plain step, looking about N.N.E. from a point south of the road.

Fig. 2.—Snowy River gorge at its exit from the Kosciusko block. Note repeated valley-in-valley structure.

Fig. 3.—View south from Brassy Peak showing the Kerries in the background and probable *roches moutonnées* on the step between Valentine River (right) and the Main Divide.

Fig. 4.—View looking from Big Brassy to the N. and N.W. The bare granite ridge running N. from Brassy Peak (on left) is a probable *roche moutonnée*. In the foreground is a step at about 5,900 feet with other smaller *roches moutonnées* on it. On the horizon is the monadnock of Jagungal.

Fig. 5.—Boulder-strewn swampy flat forming second step in the Macdonald's Creek flight. The scarp in the foreground is partly of moraine. Big Brassy (left) and Brassy Peak in background.

Fig. 6.—Looking up Macdonald's Creek towards the 400-foot scarp at the back of Alpine Hut step. Moraine in left foreground.

Plate x.

Fig. 1.—Looking up the valley of Valentine River, which in the foreground is meandering in a swampy flood-plain.

Fig. 2.—Profile of Mt. Wheatley, a probable *roche moutonnée*, as viewed from the north-east.

Fig. 3.—Looking down the Snowy River valley from the vicinity of Charlotte's Pass, showing truncated spur.

Fig. 4.—Flat-floored cirque above and N.W. of Blue Lake, with smaller cirque above it in right background.

Fig. 5.—Phyllite erratic on granite on cirque floor above Blue Lake (in middle distance). Guthrie Range on the horizon.

Fig. 6.—Snow-patches on steep wall of Club Lake cirque.

## REVISION OF AUSTRALIAN LEPIDOPTERA. OECOPHORIDAE. XII.

By A. JEFFERIS TURNER, M.D., F.R.E.S.

[Read 25th October, 1944.]

1628. *ANTIOPALA ZALOSARA*, n. sp. (*ζαλοσαρος*, storm-swept.)

♂, ♀. 19–20 mm. Head fuscous; face whitish. Palpi with second joint in male exceeding base of antennae, in female much longer (three times length of face), terminal joint in male one-fourth, in female two-thirds; fuscous, second joint with an apical white ring and internal surface whitish. Antennae ochreous-whitish with dark fuscous annulations; in male biciliated in tufts, ciliations 1. Thorax fuscous, apices of patagia and tegulae white. Abdomen grey; tuft ochreous-whitish. Legs fuscous; tarsi with whitish rings; posterior pair whitish. Forewings somewhat dilated, costa slightly arched, apex rounded, termen obliquely rounded; brownish-fuscous sprinkled with dark fuscous and whitish; markings dark fuscous; a spot on base of costa; a streak on fold; first discal at one-third, second in middle, third at two-thirds, confluent with a triangular costal spot; an outwardly curved subterminal line from four-fifths costa, becoming attenuated as it approaches, but does not reach, tornus; preceding this a broad whitish suffusion; a semi-circular spot margined with whitish on dorsum before tornus; cilia fuscous, on tornus whitish or grey. Hindwings pale grey; cilia grey-whitish.

Not near any other species. The sexual diversity in the palpi is extraordinary.

Queensland: Macpherson Rge. (Springbrook) in August and October (W. B. Barnard); two specimens. Type in Queensland Museum.

1629. *TANYZANCLA OCHROSEMA*, n. sp. (*ωχροσημος*, with pale markings.)

♂. 15 mm. Head and thorax white. Palpi with second joint very long (4), loose-scaled at apex beneath, terminal joint one-fourth; white. Antennae white with dark fuscous bars on anterior aspect; ciliations in male 4. Abdomen whitish-grey; tuft white. Legs ochreous-whitish; anterior pair grey. Forewings with costa gently arched, apex round-pointed, termen nearly straight, slightly oblique; shining white; markings pale fuscous-ochreous; a suffused longitudinal streak on upper edge of cell from one-fifth to two-fifths; a mark on end of cell, its extremities faintly prolonged posteriorly to form a crescent; a fuscous dot on three-fourths dorsum; a slender line on costa from three-fourths around apex and termen to tornus; cilia whitish-ochreous. Hindwings and cilia grey-whitish.

Queensland: Duaringa in November (W. B. Barnard); one specimen.

133. Gen. *PHILOBOTA* MEYR.

PROC. LINN. SOC. N.S.W., 1883, p. 469.

Palpi long, ascending, recurved; second joint reaching or exceeding base of antennae, but less than twice length of face, with appressed scales, sometimes loose towards apex beneath; terminal joint shorter than second (two-fifths to two-thirds), slender, acute. Antennae about two-thirds, pecten present; ciliations in male short, moderate or long (one-fourth to ten). Forewings with 7 and 8 stalked, 7 to termen. Hindwings elongate-oval; 3 and 4 connate. Type, *P. arabella*.

This very large genus, rivalled in size only by *Eulechria*, to which it is closely allied, gives rise directly to *Tanyzancla*, *Cormotypa*, *Coesyra*, *Ocystola*, *Machaeritis*, and many other genera. It is the basic genus of the immensely developed and characteristically Australian section of the Oecophoridae. The early stages of only one species (*P. productella*) are at present known.

1630. PHILOBOTA AURICEPS Butl., *Ann. Mag. Nat. Hist.*, (5) ix, p. 99. = *chrysanthes* Turn., *Trans. Roy. Soc. S. Aust.*, 1926, p. 25. = *chrystosticha* Turn., *Proc. Roy. Soc. Tasm.*, 1939, p. 95. Forewings variable; colour pale yellow to orange-yellow, markings more or less developed. (Tweed Hds., and Stanthorpe to Tasmania, Mt. Kosciusko, Mt. Lofty.)

1631. PHILOBOTA ARABELLA Newin., *Trans. Ent. Soc. Lond.*, 1855, p. 296; Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 473. (Stradbroke I., and Toowoomba to Melbourne, Katoomba, Adaminaby, Mt. Lofty.)

1632. PHILOBOTA BIOPHORA Meyr., *ibid.*, 1883, p. 476. (Birchip, Sea Lake, Adelaide, Perth, York.)

1633. PHILOBOTA ANCYLOTOXA Meyr., *ibid.*, 1883, p. 475. (Toowoomba to Melbourne, Stanthorpe, Armidale, Cooma.)

1634. PHILOBOTA IRRUPTELLA Zel., *Hor. Ross.*, 1877, p. 388, *nec* Wlk. Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 475. (Gayndah to Sydney, Injune, Mitchell, Milmerran, Birchip.)

1635. PHILOBOTA STRIGATELLA Don., *Ins. N. Holl.*, Pl. 40. = *chrysopotama* Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 476, Pl. 4, f. 7. (Stradbroke I., and Stanthorpe to Castlemaine.)

1636. PHILOBOTA PACTOLIAS Meyr., *Exot. Micro.*, i, p. 124. (Murrurundi, Cooma, Melbourne.)

1637. PHILOBOTA CATASCIA Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 476. Exceptional in the remarkable differences in the palpi of the sexes. In the male these are as usual in the genus; in the female the second joint is more than twice the length of the face as in *Tanyzancla*. (Bathurst, Gisborne, Melbourne, Moe.)

1638.† PHILOBOTA CRYPSILEUCA Meyr., *Proc. LINN. Soc. N.S.W.*, 1884, p. 732 (Mt. Wellington.)

1639. PHILOBOTA PHOENOPASTA Turn., *Proc. Roy. Soc. Tasm.*, 1926, p. 151. (Mt. Wellington, Lake Fenton.)

1640. PHILOBOTA CATALAMPRA Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 478. (Melbourne.)

1641. PHILOBOTA BORBORODES Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 90. (Mt. Kosciusko.)

1642. PHILOBOTA CERATOCHROA Turn., *ibid.*, 1917, p. 90. (Mt. Kosciusko.)

1643. PHILOBOTA MONOLITHA Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 477. (Katoomba, Mt. Kosciusko, Gisborne, Melbourne.)

1644. PHILOBOTA ISOLITHA Meyr., *Exot. Micro.*, i, p. 125. (Beaconsfield.)

1645. PHILOBOTA AGRAPHA Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 89. (Glen Innes.)

1646.† PHILOBOTA AMALODES Meyr., *Proc. LINN. Soc. N.S.W.*, 1888, p. 1626. (Fernshaw.)

1647. PHILOBOTA ANTIPODELLA Wlgrn., *Eugen. Res. Ins.*, p. 387. = *declivis* Wlk., xxix, p. 687. Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 480. = *molliculella* Wlk., xxix, p. 687. (Brisbane to Melbourne, Glen Innes, Cooma, Milmerran.)

1648.† PHILOBOTA MONOLONCHA Meyr., *Proc. LINN. Soc. N.S.W.*, 1888, p. 1607. (Melbourne.)

1649. PHILOBOTA LATIFISSELLA Wlk., xxix, p. 686; Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 480. (Ebor to Sydney and Melbourne.)

1650. PHILOBOTA HYPOCAUSTA Meyr., *ibid.*, 1883, p. 481. (Kewell, Birchip, Adelaide, Mt. Lofty.)

1651. PHILOBOTA CRYPSICHOLA Meyr., *ibid.*, 1883, p. 482. (Katoomba, Bathurst, Orange, Gisborne, Melbourne, Moe.)

1652. PHILOBOTA XIPHOSTOLA Meyr., *ibid.*, 1883, p. 482. = *phauloscopa* Meyr., *ibid.*, 1883, p. 484. (Sydney, Orange, Adaminaby, Victoria, Mt. Lofty.)

1653. PHILOBOTA LONCHOTA Turn., *Trans. Roy. Soc. S. Aust.*, 1896, p. 23. (Noosa, Brisbane, Stradbroke I., Tweed Hds.)

1654. PHILOBOTA NEPHELARCHA Meyr., *Proc. LINN. Soc. N.S.W.*, 1883, p. 483. (Ebor, Deloraine.)

1655. *PHILOBOTA ALLOEA*, n. sp. (*ἀλλοιος*, distinct, different.)

♂. 24-26 mm. Head pale yellow. Palpi with terminal joint three-fifths; fuscous, terminal joint whitish on internal surface. Antennae dark fuscous with grey annulations except towards base; ciliations in male 1. Thorax pale yellow; a posterior dot and tegulae dark fuscous. Abdomen fuscous. Legs fuscous; posterior pair whitish-ochreous beneath. Forewings with costa slightly arched, apex rounded, termen obliquely rounded; pale yellow; markings dark fuscous; a narrow basal fascia with short costal, subcostal, and dorsal acute projections; stigmata minute, first discal at one-fourth or absent, plical slightly beyond, second discal at three-fifths; a short oblique costal mark at four-fifths, sometimes emitting a slender interrupted line to tornus; cilia pale yellow. Hindwings grey; cilia whitish-grey.

Queensland: Ebor in December; five specimens.

1656. *PHILOBOTA THIOPGRAMMA* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1607. (Adelaide, Mt. Lofty.)

1657. *PHILOBOTA MITOLOMA* LOW., *ibid.*, 1915, p. 480. (Pinnaroo.)

1658. *PHILOBOTA MELANOXANTHA* MEYR., *ibid.*, 1888, p. 1608. (Albany, Waroona, Perth, Yanchep.)

1659. *PHILOBOTA MICROXANTHA* MEYR., *ibid.*, 1888, p. 1615. (Albany, Margaret R., Busselton, Yanchep.)

1660.† *PHILOBOTA LYSIZONA* MEYR., *ibid.*, 1888, p. 1609. (Bathurst.)

1661. *PHILOBOTA CHARAXIAS* MEYR., *ibid.*, 1888, p. 1641. (Ebor, Victoria, Tasmania.)

1662. *PHILOBOTA EUDELA*, n. sp. (*εὐδῆλος*, very clear.)

♂. 18-22 mm. Head and thorax white. Palpi with second joint three-fifths; white, second joint blackish towards base. Antennae blackish finely annulated with white, basal joint white; ciliations in male 2 and one-half. Abdomen ochreous-grey; apices of segments and tuft whitish. Legs blackish with white rings; posterior pair whitish-ochreous. Forewings narrow, costa slightly arched, apex round-pointed, termen very obliquely rounded; white with clearly defined black markings; a narrow fascia from base of costa to one-third dorsum, its outer edge angled below middle; first discal at one-third, plical well beyond; second discal at two-thirds, forming the apex of a triangular costal spot; a dot on one-fourth costa; a small triangle on costa near apex, emitting a fine interrupted line to tornus; cilia ochreous-whitish. Hindwings grey-whitish; cilia as forewings.

Queensland: Injune in August and September (W. B. Barnard); three specimens. Type in Queensland Museum.

1663. *PHILOBOTA LEUCOZANCLA*, n. sp. (*λευκοζαγκλος*, with white sickles.)

♂. 24 mm. Head white. Palpi with terminal joint three-fifths; white, basal half of outer surface of second joint dark fuscous. Antennae fuscous; ciliations in male extremely long (8). Thorax blackish; an anterior spot and lateral margins white. Abdomen ferruginous; apices of segments white. Legs fuscous with white rings; posterior tibiae whitish. Forewings dilated posteriorly, costa gently arched, apex pointed, termen straight, oblique; white with blackish markings; an elongate spot on base of costa; a narrow wedge on one-third costa; a thick line on fold closely approximated or united with this, giving off a short bar towards base of dorsum, and a line to two-fifths dorsum; a very irregular fascia from two-thirds costa to tornus, enclosing a central white dot; a large apical spot slenderly produced on termen; cilia white, on apex and tornus fuscous. Hindwings and cilia pale grey.

New South Wales: Mt. Kosciusko (5,000 ft.) in December; one specimen. Type in Coll. Goldfinch.

1664. *PHILOBOTA GONIOTYPA*, n. sp. (*γωνιοτυπος*, with angular markings.)

♂. 20 mm. Head white. Palpi with terminal joint three-fifths; white, outer surface of second joint fuscous towards base. Antennae white with fuscous annulations; ciliations in male 3. Thorax white; lateral and posterior margins broadly dark fuscous. Abdomen pale grey. Legs fuscous; posterior pair whitish. Forewings with costa rather strongly arched, apex acutely pointed, termen straight, oblique; white with dark fuscous markings; a costal streak from base to one-fourth; a broad line from midcosta inwards to fold at one-fourth, there acutely angled outwards, broader and rather diffused to

three-fourths dorsum; a fine line from midcosta to tornus; a series of triangular dots united by a fine terminal line; cilia fuscous, on tornus white. Hindwings and cilia grey-whitish.

Tasmania: Hobart in January (W. B. Barnard); one specimen.

1665. *PHILOBOTA HYPHANTA* Turn., *Proc. Roy. Soc. Tasm.*, 1926, p. 153. (Lake Fenton.)

1666. *PHILOBOTA EURYTOXA*, n. sp. (*εὐρυτοξος*, with a wide bow.)

♀. 16 mm. Head whitish-ochreous. Palpi with terminal joint three-fifths; whitish, second joint fuscous towards base. Antennae fuscous. Thorax blackish with a white posterior spot. Abdomen dark fuscous. Legs fuscous. Forewings narrow, costa slightly arched, apex pointed, termen nearly straight, oblique; blackish with white markings; a basal spot; a broad outwardly curved sub-basal fascia with a median posterior projection; an inwardly oblique line from costa at three-fifths to middle of disc; a costal dot before apex, another on dorsum before tornus, and another on midtermen; cilia dark fuscous. Hindwings and cilia dark fuscous.

Queensland: Macpherson Rge. (3,000 ft.) in November; one specimen.

1667. *PHILOBOTA CROCOPLEURA*, n. sp. (*κροκοπλευρος*, with saffron costa.)

♂. 20-22 mm. Head orange-yellow. Palpi with terminal joint three-fifths; whitish-ochreous. Antennae grey, basal joint fuscous; ciliations in male 1. Thorax dark fuscous with anterior, posterior, and lateral yellow spots. Abdomen grey; apices of segments and tuft pale yellow. Legs yellow; anterior pair fuscous with yellow rings. Forewings with costa gently arched, apex round-pointed, termen slightly rounded, slightly oblique; white; an orange-yellow costal streak from near base to apex; markings blackish; a basal fascia, its outer edge acutely angled, containing a basal orange-yellow dot; a short bar from near base of dorsum to fold; beyond this an oblique bar from near base of costa to fold; a short subcostal streak beyond middle; a triradiate mark above tornus; a short inwardly oblique costal streak, continued as a submarginal line to tornus; cilia whitish-ochreous. Hindwings pale grey; cilia as forewings.

West Australia: Albany and Denmark in November; five specimens.

1668. *PHILOBOTA EUARMOSTA*, n. sp. (*εὐαρμωστος*, harmonious.)

♂. 28 mm. Head whitish-ochreous. Palpi with terminal joint two-thirds; fuscous, terminal joint and apex of second white. Antennae fuscous with whitish rings; ciliations in male one-half. Thorax white; bases of tegulae and terminal edge dark fuscous. Abdomen grey; apices of segments and tuft whitish-ochreous. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa gently arched, apex round-pointed, termen slightly rounded, strongly oblique; white with dark fuscous markings; a straight narrow sub-basal fascia; a short line from costa beyond middle strongly oblique inwards; first discal at one-third, plical beneath it, second discal at three-fifths, transversely curved, connected by a line with tornus; a minute dot above plical; a suffused apical spot; cilia white. Hindwings and cilia whitish-ochreous.

New South Wales: Barrington Tops in December; one specimen. Type in Coll. Goldfinch.

1669. *PHILOBOTA NIPHIAS* MEYR., *Proc. Linn. Soc. N.S.W.*, 1884, p. 730. (Hobart.)

1670. *PHILOBOTA MYCHIAS* MEYR., *ibid.*, 1888, p. 1639. (Yanchep, Geraldton.)

1671. *PHILOBOTA EPITOXIA* MEYR., *ibid.*, 1888, p. 1637. (Waroona, Mogumber, Geraldton, Carnarvon.)

1672. *PHILOBOTA AMPHITOXIA* MEYR., *ibid.*, 1888, p. 1640. (Mt. Lofty, Waroona, Perth, Geraldton.)

1673. *PHILOBOTA CAMPYLOSEMA*, n. sp. (*καμπυλοσημος*, with bent markings.)

♂. 21-22 mm. Head orange. Palpi with terminal joint two-thirds; orange, anterior edge of terminal joint fuscous. Antennae fuscous; ciliations in male two-thirds. Thorax blackish; posterior edge and tegulae pale yellow. Abdomen grey; tuft pale yellow. Legs blackish; posterior tibiae pale yellow. Forewings narrow, costa slightly arched, apex rounded, termen obliquely rounded; pale yellow with blackish markings; a narrow sub-basal fascia; a transverse line at one-third, bent outwards to mid-dorsum and also to two-thirds costa, but upper portion sometimes incomplete; an irregular line from two-thirds costa to tornus, bent on costa towards apex; an apical spot giving out a fine line

to tornus; cilia pale yellow, on apex and tornus fuscous. Hindwings grey; cilia grey, sometimes tinged yellowish.

West Australia: Margaret R. in November; Waroona in October; two specimens.

1674. *PHILOBOTA TETRAGONA* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1623. (Albany, Waroona.)

1675. *PHILOBOTA AMOEBAEA* MEYR., *ibid.*, 1888, p. 1623. (Perth, Yanchep.)

1676.† *PHILOBOTA ECHIDNIAS* MEYR., *ibid.*, 1888, p. 1624. (Geraldton.)

1677.† *PHILOBOTA GYMNASSTICHA* MEYR., *Exot. Micro.*, ii, p. 314. (Cape Naturaliste.)

1678.† *PHILOBOTA CHIASTIS* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1606. (W. Aust., York.)

1679. *PHILOBOTA XANTHOPREPES* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 85. (Cape York, Atherton.)

1680. *PHILOBOTA XANTHODISCA*, n. sp. (*ξανθοδισκος* with yellow blotches.)

♂, ♀. 22–28 mm. Head yellow. Palpi with terminal joint three-fifths; yellow. Antennae grey; ciliations in male 1. Thorax dark fuscous; tegulae and a posterior spot yellow. Abdomen grey; tuft ochreous. Legs fuscous; posterior pair ochreous. Forewings elongate, costa straight except near base and apex, apex rounded, termen very obliquely rounded; dark fuscous with yellow markings; a basal line from costa to dorsum; a sub-basal costal blotch terminating in a point nearly reaching one-third dorsum; a large median spot connected with another on two-thirds costa; an irregular spot touching two-thirds dorsum; a median circular spot before termen; cilia dark fuscous. Hindwings and cilia fuscous.

North Queensland: Cooktown in May (W. B. Barnard); four specimens. Type in Queensland Museum.

1681.† *PHILOBOTA MECHANICA* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1581. (Stawell, Gisborne.)

1682.† *PHILOBOTA GRAMMOPHORA* LOW., *ibid.*, 1897, p. 21. Placed here conjecturally. (Gisborne.)

1683. *PHILOBOTA TESSARADISCA*, n. sp. (*τεσσαραδισκος*, with four blotches.)

♀. 18 mm. Head whitish-ochreous. Palpi slender, second joint just reaching base of antennae, terminal joint three-fifths; fuscous. Antennae fuscous. Thorax fuscous, posteriorly mixed with whitish-ochreous. Abdomen ochreous. Legs fuscous; posterior tibiae pale ochreous. Forewings with costa slightly rounded, apex pointed, termen very oblique; pale fuscous with four whitish-ochreous blotches; first sub-basal, large, narrowly separated from costa and dorsum; second beneath three-fifths costa; third above two-thirds dorsum; fourth sub-oval, larger, subterminal; cilia pale fuscous. Hindwings grey; cilia whitish-ochreous.

West Australia: Merredin in September; one specimen.

1684. *PHILOBOTA CONTENTELLA* Wlk., xxx, p. 1031. MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 515. (Tweed Hds., Sydney, Melbourne, Adelaide.)

1685. *PHILOBOTA IMPLETTELLA* Wlk., *Char. Undesc. Lepid.*, p. 87. = *herodiella* Feld., Pl. 40, f. 31. MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 489. (Katoomba, Mt. Kosciusko, Victoria, Mt. Lofty.)

1686. *PHILOBOTA LEPTOMITA*, n. sp. (*λεπτομιτος*, with fine threads.)

♀. 18 mm. Head white. Palpi with terminal joint one-half; fuscous, apex and inner surface of second joint white. Antennae fuscous. Thorax fuscous; apices of tegulae white. Abdomen grey. Legs grey. Forewings narrow, costa slightly arched, apex pointed, termen sinuate, oblique; white; markings fuscous; a short streak on costa from base; a sub-basal transverse line; a line from costa beyond middle obliquely inwards to beneath one-third costa, thence dentate and transverse to two-fifths dorsum; a line from three-fourths costa, soon bifurcating, its inner limb to two-thirds dorsum, outer limb to tornus; a dot just before apex; a short terminal line from apex; cilia white, on apex and tornus fuscous. Hindwings and cilia pale grey.

West Australia: Coorow in October; one specimen.

1687. *PHILOBOTA ORTHOMOCHLA*, n. sp. (*ὀρθομοχλος*, straight barred.)

♀. 22 mm. Head white. Palpi with terminal joint two-thirds; grey, terminal joint and base of second joint whitish. Antennae pale grey. Thorax white; posterior half

dark fuscous. Abdomen grey; apices of segments and tuft whitish. Forewings with costa gently arched, apex round-pointed; termen straight, oblique; white; a narrow dark fuscous basal fascia; a moderate transverse fascia at two-fifths; a similar fascia at four-fifths; an apical spot; some small terminal dots; cilia white, on tornus fuscous. Hindwings grey; cilia ochreous-whitish.

Queensland: Maryland, near Stanthorpe, in November (W. B. Barnard); one specimen.

1688. *PHILOBOTA DIMOCHLA*, n. sp. (*διμοχλος*, with two bars.)

♀, ♂. 15–18 mm. Head white. Palpi with second joint just reaching base of antennae, terminal joint three-fifths; white. Antennae grey; ciliations in male 1 and one-half. Thorax dark fuscous with anterior and posterior white spots. Abdomen grey; tuft whitish-ochreous. Legs whitish-ochreous. Forewings rather narrow, sub-oblong, costa gently arched, apex rectangular, termen nearly straight, slightly oblique; white; markings dark fuscous; a narrow basal fascia; a moderate median fascia from two-fifths costa to mid-dorsum, broader on dorsum, posterior edge angled in middle; a narrow fascia from four-fifths costa to tornus; a slender line on apical fifth of costa and termen, on latter edged anteriorly with ochreous; cilia ochreous, on apex and tornus fuscous. Hindwings and cilia grey.

Queensland: Toowoomba in November and December (W. B. Barnard); two specimens. Type in Queensland Museum.

1689. *PHILOBOTA CAMPOSEMA*, n. sp. (*καμποσημος*, with bent marking.)

♀. 18 mm. Head white. Palpi with terminal joint three-fifths; terminal joint and apex of second joint fuscous. Forewings narrow, costa scarcely arched, apex rounded, termen very obliquely rounded; white with fuscous markings; a narrow basal fascia; a line from one-third costa to two-fifths dorsum; a narrow fascia from two-thirds costa obliquely inwards, bent outwards in disc to end on tornus; its extremities joined by an outwardly curved line; a short terminal line from apex; cilia whitish-ochreous, on tornus fuscous. Hindwings and cilia grey.

Queensland: Toowoomba in October (W. B. Barnard); two specimens. Type in Queensland Museum.

1690. *PHILOBOTA DELOSEMA* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 87. (Stanthorpe.)

1691. *PHILOBOTA ANARRECTA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1620. (Ebor, Barrington Tops, Mt. Kosciusko, Gisborne, Melbourne.)

1692. *PHILOBOTA AVANTIS* Meyr., *ibid.*, 1888, p. 1642. = *eucria* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 87. (Brisbane, Melbourne, Kewell.)

1693. *PHILOBOTA HABROSEMA*, n. sp. (*αβροσημος*, softly marked.)

♂. 17 mm. Head white. Palpi with terminal joint three-fifths; white, outer surface of second joint, except apex, fuscous. Antennae white annulated with fuscous; ciliations in male 1. Thorax fuscous. (Abdomen missing.) Legs whitish-ochreous; anterior pair fuscous. Forewings with costa moderately arched, apex rounded, termen obliquely rounded; white; markings ochreous-grey; a dot on base of costa prolonged on costal edge; a narrow transverse fascia at one-third, not reaching costa; united by a longitudinal line with the upper end of a second fascia from beneath two-thirds costa to tornus; a terminal band, broadest on costa; cilia brownish-ochreous. Hindwings pale grey; cilia grey-whitish.

New South Wales: Cudgen Hds., near Tweed Hds., in November (W. B. Barnard); one specimen.

1694. *PHILOBOTA MACULOPA* Low., *Trans. Roy. Soc. S. Aust.*, 1903, p. 224. This and the following are not near any other species. (S. Aust.: Halbury.)

1696. *PHILOBOTA ALLOCOTA*, n. sp. (*αλλοκοτος*, unusual.)

♂, ♀. 16–18 mm. Head and thorax white. Palpi with terminal joint one-half; white. Antennae grey, towards base whitish; ciliations in male 2 and one-half. Abdomen grey; tuft whitish. Legs grey; posterior pair whitish. Forewings with costa strongly arched, apex pointed, termen sinuate, slightly oblique; a white transverse basal line; a quadrate white spot on one-third dorsum, sometimes enclosing a fuscous dot; a narrow fuscous fascia from one-third costa to mid-dorsum, broader towards dorsum, edged by a white line posteriorly; a white line from costa near apex, broader near costa to tornus, sharply

incurved in disc; edged by a fuscous line anteriorly, posteriorly by fuscous suffusion; cilia white, apices above midtermen fuscous. Hindwings and cilia pale grey.

West Australia: Albany in February (W. B. Barnard); two specimens. Type in Queensland Museum.

1697. *PHILOBOTA LOCHITIS* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 87. (Mt. Tamborine.)

1698. *PHILOBOTA DASYCOPA* Low., *ibid.*, 1907, p. 117. (S. Aust.: Macdonnel Bay.)

1699.† *PHILOBOTA THARSYNTIS* Meyr., *Arkiv. f. Zool.*, xiv (15), p. 8. (Kimberley.)

1700. *PHILOBOTA ERISCOTA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1612. (Stanthorpe, Glen Innes.)

1701. *PHILOBOTA ARCHEDORA*, n. sp. (*ἀρχεδωρος*, excellent.)

♀. 21 mm. Head white. Palpi with terminal joint one-half; white. Antennae fuscous, pecten white. Thorax dark fuscous; apices of tegulae white. Abdomen grey. Legs fuscous; posterior pair whitish-ochreous. Forewings elongate, costa gently arched, apex pointed, termen nearly straight, very oblique; white with dark fuscous markings; a thick costal streak from base to middle; a large quadrate spot on mid-dorsum, touching costal streak; a moderate fascia from three-fourths costa to tornus, giving off anteriorly a fine line to dorsal spot, and excavated beneath this; a large apical spot; cilia fuscous. Hindwings grey; cilia whitish-ochreous, around apex grey.

Victoria: Gisborne in February; one specimen received from Mr. Geo. Lyell. Type in National Museum, Melbourne.

1702. *PHILOBOTA PSILOPLA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1884, p. 735. (Gosford, Sydney, Melbourne.)

1703. *PHILOBOTA AMECHANA*, n. sp. (*ἀμυχανος*, feeble.)

♂. 12 mm. Head yellow. Palpi with terminal joint three-fifths; pale yellow. Antennae fuscous; ciliations in male 1. Thorax and abdomen fuscous. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa moderately arched, apex rounded, termen straight, oblique; fuscous; markings yellow; a moderate sub-basal fascia not quite reaching costa; a triangular spot on dorsum just before tornus; cilia fuscous, apices except on apex and tornus ochreous-whitish. Hindwings and cilia fuscous.

North Queensland: Kuranda in September; one specimen received from Mr. F. P. Dodd.

1704. *PHILOBOTA MESODESMA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1642. (Broken Hill, Stawell, Birchip, York.)

1705. *PHILOBOTA BRACATEATELLA* Wlk., xxix, p. 696. Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 502. = *subductella* Wlk., xxix, p. 695. (Noosa and Stanthorpe to Melbourne, Mt. Lofty, Albany.)

1706. *PHILOBOTA TRIJUGELLA* Zel., *Hor. Ross.*, 1877, p. 391. Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 503. (Stradbroke I., Tweed Hds., Sydney, Bathurst, Melbourne, Mt. Lofty.)

1707. *PHILOBOTA MEGALOCENTRA* Meyr., *ibid.*, 1888, p. 1619. (Dimboola, Nhill, Adelaide, Waroona, Perth, Geraldton.)

1708. *PHILOBOTA LATHICENTRA* Meyr., *ibid.*, 1888, p. 1618. (Adelaide, Albany to Carnarvon.)

1709. *PHILOBOTA INTERLINEATELLA* Wlk., xxix, p. 692. Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 501. (Sydney to Melbourne, Adelaide, Pt. Lincoln, Albany to Geraldton.)

1710. *PHILOBOTA GONOSEMA* Meyr., *ibid.*, 1887, p. 952. = *porphyryxantha* Low. *Trans. Roy. Soc. S. Aust.*, 1893, p. 381. (Stawell, Kewell, Mt. Lofty.)

1711. *PHILOBOTA SIPHONISTIS* Meyr., *Exot. Micro.*, ii, p. 385. (Dalby.)

1712. *PHILOBOTA SOPHIA* Turn., *Trans. Roy. Soc. S. Aust.*, 1896, p. 26. (Warwick, Stanthorpe, Glen Innes, Armidale, Scone.)

1713. *PHILOBOTA PARTITELLA* Wlk., xxix, p. 683. Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 491. (Murrumbidgee, Sydney, Katoomba, Melbourne.)

1714. *PHILOBOTA HABRODES* Low., *ibid.*, 1899, p. 108. (Broken Hill, Birchip.)

1715. *PHILOBOTA GEPHYRODES*, n. sp. (*γεφυρωδης*, like a bridge [referring to markings on forewings].)

♀. 25–30 mm. Head orange. Palpi with terminal joint two-thirds; orange. Antennae grey. Thorax white; anterior edge narrowly fuscous. Abdomen grey; apices of segments and tuft whitish-ochreous. Legs fuscous; posterior pair pale ochreous. Forewings elongate, narrow, costa arched at base, thence straight almost to apex, apex round-pointed, termen very obliquely rounded; white; markings fuscous; a median sub-basal dot; first discal at one-third, plical before and often connected with it; second discal at two-thirds, connected with the end of a subcostal line running from first discal; this line ends in two streaks running to costa before apex; a slender terminal line linked in one example by a curved line with these streaks; cilia ochreous-whitish. Hindwings grey; cilia as forewings.

Queensland: Injune in April and May (W. B. Barnard); seven specimens, all female. Type in Queensland Museum.

1716. *PHILOBOTA ACROPOLA* MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 485. (Mt. Macedon, Fernshaw.)

1717. *PHILOBOTA OLYMPIAS* MEYR., *ibid.*, 1888, p. 1610. (Mt. Kosciusko, Victoria, Tasmania.)

1718. *PHILOBOTA SPHENOLEUCA* LOW., *Trans. Roy. Soc. S. Aust.*, 1907, p. 117. (Melbourne, Birchip, S. Aust., Balaclava, Gawler.)

1719.† *PHILOBOTA MADIDA* MEYR., *Exot. Micro.*, ii, p. 384. (Hobart.)

1720. *PHILOBOTA ORINOMA* MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 484. (Stanthorpe, Mittagong, Victoria.)

1721.† *PHILOBOTA PROFUGA* MEYR., *Exot. Micro.*, i, p. 132. (Cairns.)

1722. *PHILOBOTA NEPHELOTA*, n. sp. (*νεφελωτος*, clouded.)

♂. 25–27 mm. Head ochreous-whitish. Palpi with terminal joint three-fifths; fuscous, terminal joint and apex of second joint ochreous-whitish. Antennae fuscous; ciliations in male 1 and one-half. Thorax ochreous-whitish; anterior border broadly fuscous. Abdomen fuscous; tuft whitish-ochreous. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa slightly arched, apex rounded, termen obliquely rounded; ochreous-whitish with pale grey suffusion except near costa; markings fuscous; a basal fascia with dentate posterior edge; an inwardly oblique mark on midcosta and another on three-fourths; first discal at one-third, plical absent, second discal at two-thirds, double; some dark fuscous terminal dots; cilia ochreous-whitish. Hindwings pale grey; cilia ochreous-whitish. New South Wales: Mt. Kosciusko in December; four specimens. Type in Coll. Goldfinch.

1723. *PHILOBOTA PLATYPTERA* LOW., *Trans. Roy. Soc. S. Aust.*, 1893, p. 180. (Adelaide.)

1724. *PHILOBOTA HIRACISTIS* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1609. = *grammidias* MEYR., *Exot. Micro.*, i, p. 133. (Duaranga.)

1725. *PHILOBOTA ECCLETA*, n. sp. (*ἐκκλητος*, picked out.)

♂, ♀. 24–30 mm. Head whitish-ochreous. Palpi with terminal joint three-fifths; fuscous, terminal joint and apex of second joint white. Antennae grey; ciliations in male two-thirds. Thorax white; tegulae, and in female a subterminal bar, dark fuscous. Abdomen ochreous-whitish; bases of segments more or less fuscous. Legs fuscous; posterior pair ochreous-whitish. Forewings elongate, posteriorly dilated, costa slightly arched, apex rounded, termen rounded, strongly oblique; white with some fuscous suffusion on dorsum; markings dark fuscous; a broad streak from base of dorsum to and along costa enclosing a white basal dot, narrowing to a point at two-thirds costa; first discal at one-fourth, plical beneath it, second discal at three-fifths, transversely curved, a dot above middle touching costal streak; an inwardly curved oblique bar from costa near apex to tornus, giving off a fine interrupted outwardly curved line, which joins it again at tornus; an irregular terminal spot beneath apex, followed by terminal dots to tornus; cilia white with an antemedian series of fuscous dots. Hindwings whitish-grey; cilia whitish.

New South Wales: Cooma in October; ten specimens.

1726. *PHILOBOTA PYCNOTYPA*, n. sp. (*πυκνοτυπος*, thickly marked.)

♂, ♀. 30–34 mm. Head white. Palpi with terminal joint three-fifths; fuscous; apex of second joint white. Antennae fuscous; ciliations in male one-half. Thorax white; anterior and posterior margins and tegulae dark fuscous. Abdomen grey; apices of

segments whitish; tuft ochreous-whitish. Legs fuscous; posterior pair ochreous-whitish. Forewings sub-oblong, costa gently arched, apex rounded, termen obliquely rounded; white; markings dark fuscous; a sub-basal transverse line; a costal streak from one-sixth to two-thirds or less, attenuated at extremities; stigmata large, first discal at one-fourth, plical slightly beyond, second discal beyond middle, transversely curved, sometimes its lower end joined with plical to form a sigmoid curve; a dot above and between discals; a short inwardly oblique costal bar from costa before apex giving off a curved line to tornus; an apical spot and a terminal series of dots; cilia grey with a basal series of pale fuscous dots, apices partly white. Hindwings and cilia grey.

New South Wales: Mt. Kosciusko (3,500-5,000 ft.) in January; three specimens.

1727. *PHILOBOTA IPHIGENES* MEYR., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1614. (Mt. Kosciusko, Victoria, Mt. Lofty.)

1728. *PHILOBOTA MYLOTHRIS* MEYR., *Exot. Micro.*, ii, p. 385. (Brisbane, Stanthorpe, Murrurundi.)

1729. *PHILOBOTA EUNETA*, n. sp. (*εὐνητος*, well woven.)

♂. 18-20 mm. Head ochreous-whitish. Palpi with terminal joint three-fifths; fuscous, terminal joint and apex of second ochreous-whitish. Antennae fuscous; ciliations in male 1. Thorax ochreous-whitish; bases of tegulae fuscous. Abdomen grey. Legs fuscous; posterior pair ochreous-whitish. Forewings with costa slightly arched, apex rounded, termen very obliquely rounded; ochreous-whitish with slight fuscous irroration; markings dark fuscous; an oblong basal spot; a short outwardly oblique line from one-third costa, its apex representing first discal, plical beneath it, second discal at three-fifths, outwardly curved, a dot above and between discals; a slender line from costa near apex obliquely inwards, soon sharply angled, thence curved to tornus; cilia ochreous-whitish with a basal series of fuscous dots. Hindwings and cilia pale grey.

Victoria: Mt. Macedon in November (W. E. Drake); four specimens. Type in National Museum.

1730. *PHILOBOTA ORESCOA* MEYR., *Proc. Linn. Soc. N.S.W.*, 1883, p. 376. (Injune and Milmeran to Gisborne, St. Helens, Mt. Lofty.)

1731. *PHILOBOTA POLYBOTRYA* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 93. (Mt. Macedon.)

1732. *PHILOBOTA AEDOPHANES*, n. sp. (*αιδοφανης*, modest.)

♂, ♀. 15-18 mm. Head ochreous-whitish. Palpi with terminal joint three-fifths; fuscous, terminal joint and apex of second joint ochreous-whitish. Antennae grey; ciliations in male 1. Thorax whitish; anteriorly broadly fuscous. Abdomen grey; apices of segments and tuft whitish. Legs fuscous with whitish rings; posterior pair ochreous-whitish. Forewings with costa gently arched, apex round-pointed, termen obliquely rounded; whitish; markings fuscous; a spot on base of costa; triangular costal spots at one-third and two-thirds; first discal at one-third, plical beneath or slightly beyond, second discal at two-thirds; a dot above and between discals, another beneath second discal; an irregular suffused fascia from costa before apex to tornus; cilia whitish. Hindwings and cilia pale grey.

North Queensland: Cairns and Palm I. in June; six specimens.

1733. *PHILOBOTA PILIDIOTA* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 95. = *deltoloma* Low., *ibid.*, 1923, p. 55. (Nambour, Brisbane, Tweed Hds., Dorrigo, Allyn R.)

1734. *PHILOBOTA MELANOGLYPTA* MEYR., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1614. (Bathurst.)

1735.† *PHILOBOTA OBLIVIOSA* MEYR., *Exot. Micro.*, i, p. 124. (Atherton.)

1736. *PHILOBOTA INTRICATA*, n. sp. (*intricatus*, confused.)

♂. 24 mm. Head white. Palpi with terminal joint two-thirds; white sprinkled with dark fuscous. Antennae fuscous, basal joint partly white; ciliations in male one-half. Thorax dark fuscous; apices of tegulae and three posterior spots white. Abdomen grey; apices of segments and tuft pale ochreous. Legs fuscous with ochreous-whitish rings; posterior pair whitish-ochreous. Forewings narrow, costa moderately arched, apex pointed, termen nearly straight, oblique; dark fuscous with white markings; a large white spot on base of dorsum; a suffused spot on costa before middle reaching half across disc, enclosing a central dark dot; a somewhat similar spot on dorsum

beyond middle, connected by a broad streak with three-fourths costa; a crenulate terminal line; cilia fuscous with postmedian whitish-ochreous bars. Hindwings grey; cilia pale ochreous.

Queensland: Killarney in January (W. B. Barnard); one specimen.

1737.† *PHILOBOTA DIFFUSA* Luc., *Proc. Roy. Soc. Qd.*, 1901, p. 89. (Brisbane.)

1738. *PHILOBOTA PRUINOSA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 495. (Brisbane to Castlemaine, Stanthorpe, Glen Innes.)

1739. *PHILOBOTA HAPALA* Meyr., *ibid.*, 1883, p. 459. (Katoomba.)

1740. *PHILOBOTA DISEMA* Meyr., *ibid.*, 1884, p. 786. (Sydney.)

1741.† *PHILOBOTA NOSERODES* Meyr., *ibid.*, 1888, p. 1658. (Warragul.)

1742.† *PHILOBOTA AMPHILYCA* Meyr., *ibid.*, 1884, p. 787. (Sydney.)

1743. *PHILOBOTA LOCHMAULA* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 96. (Atherton, Mt. Tamborine, Tweed Hds.)

1744. *PHILOBOTA XYLOCHROA* Low., *Proc. Linn. Soc. N.S.W.*, 1893, p. 179. (Kewell, Nhill, Birchip, Adelaide.)

1745. *PHILOBOTA LEUCOMITRA* Meyr., *ibid.*, 1883, p. 488. (Warwick, Katoomba, Mt. Kosciusko, Mt. Wellington.)

1746. *PHILOBOTA AUXOLYCA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1610. (Ebor, Mt. Kosciusko.)

1747. *PHILOBOTA METACNECA*, n. sp. (*μετακνηκος*, posteriorly yellowish.)

♂. 23–26 mm. Head whitish-ochreous. Palpi with terminal joint three-fifths; pale grey. Antennae fuscous; ciliations in male two-thirds. Thorax dark fuscous; posteriorly whitish-grey. Abdomen brownish; apices of segments and tuft ochreous. Legs fuscous; posterior pair whitish-ochreous. Forewings rather narrow, costa gently arched, apex round-pointed, termen very obliquely rounded; whitish-grey; markings dark fuscous; a narrow basal fascia; first discal at one-fourth, plical beneath it, a dot above and between discals, second discal at three-fifths, crescentic; sometimes a broad line from four-fifths to tornus, touching second discal, sending off a slender outwardly curved line to tornus; a slight apical suffusion and slender terminal line; cilia grey-whitish, on apex fuscous. Hindwings and cilia pale yellow.

New South Wales: Ebor and Allyn R. in December; two specimens.

1748. *PHILOBOTA ATMOBOLA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 486. (Tasmania.)

1749. *PHILOBOTA PROTORTHRA* Meyr., *ibid.*, 1883, p. 378. (Gisborne, Cradle Mt., Mt. Wellington, Lake Fenton.)

1750.† *PHILOBOTA AXIOTA* Meyr., *ibid.*, 1888, p. 1604. (Vict.: Warragul.)

1751. *PHILOBOTA SCIEROPA* Meyr., *ibid.*, 1888, p. 1911. (Adaminaby, Mt. Kosciusko.)

1752.† *PHILOBOTA TRIVIA* Meyr., *Exot. Micro.*, i, p. 303. (Sydney.)

1753. *PHILOBOTA HYDARA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 494. = *orphnites* Turn., *Trans. Roy. Soc. S. Aust.*, 1896, p. 24. = *fulvifusa* Turn., *Proc. Linn. Soc. N.S.W.*, 1916, p. 34. = *holmodes* Meyr., *Exot. Micro.*, ii, p. 510. The genus *Atribasta* Turn., was made for an abnormal example of this species with 7 and 8 coincident in both forewings. (Duaranga, Brisbane, Macpherson Rge., Toowoomba, Warwick.)

1754. *PHILOBOTA PRODUCTELLA* Wlk., xxix, p. 688; Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 496. = *griseicostella* Zel., *Hor. Ross.*, 1877, p. 395. Mr. G. F. Hill discovered the larvae in silken tubes among the roots of grasses, damaging pasture land. This has since been confirmed by other observers. (Toowoomba to Melbourne, Ebor, Birchip, South Australia.)

1755. *PHILOBOTA TANAOSTOLA*, n. sp. (*ταναοστολος*, long-robed.)

♂. 30–38 mm. Head and thorax fuscous. Palpi slender, terminal joint two-fifths; grey. Antennae grey; ciliations in male 3. Abdomen and legs grey. Forewings elongate, narrow, posteriorly dilated, costa slightly arched, more strongly towards apex, apex round-pointed, termen very obliquely rounded; grey; markings fuscous; a fine subcostal streak from base, sometimes as far as one-fourth; another on fold; a third, more or less interrupted, on lower edge of posterior half of cell, turning abruptly upwards on end of cell; streaks on radial veins; a curved subterminal series of dots; a series of short streaks running to termen; in a few examples a broad median streak from base

dividing into fine streaks before termen; cilia grey. Hindwings and cilia grey. Somewhat variable.

Queensland: Injune in May, June, July, August and September (W. B. Barnard); a long series, all male. Type in Queensland Museum.

1756. *PHILOBOTA SPODOTIS*, n. sp. (*σποδοτῖς*, ash-grey.)

♂. 28-30 mm. Head and thorax fuscous. Palpi with second joint exceeding base of antennae, terminal joint three-fifths; fuscous. Antennae fuscous; ciliations in male 3. Abdomen grey. Legs fuscous; posterior pair grey-whitish. Forewings narrow towards base, posteriorly dilated, costa slightly arched, apex rounded, termen obliquely rounded; dark grey sparsely sprinkled with fuscous; an obscure fuscous subterminal line from five-sixths costa, indented beneath costa, thence curved to dorsum near tornus; minute terminal fuscous dots; cilia grey with a sub-basal fuscous line. Hindwings and cilia grey-whitish.

Queensland: Maryland, near Stanthorpe, in June and July (W. B. Barnard); two specimens. Type in Queensland Museum.

1757. *PHILOBOTA CONIODES*, n. sp. (*κονιωδῆς*, dusty.)

♂, ♀. 27-30 mm. Head grey. Palpi with terminal joint one-half; fuscous, apex of second joint whitish. Antennae grey; ciliations in male 1. Thorax fuscous. Abdomen fuscous; apices of segments and tuft whitish. Legs fuscous; posterior pair whitish. Forewings with costa moderately arched, apex round-pointed, termen obliquely rounded; grey lightly sprinkled with fuscous; markings fuscous; first discal at one-fourth, plical beneath it, second discal at middle, a dot above and between discals; a slender interrupted line from three-fourths costa obliquely outwards, bent above middle, thence submarginal to tornus; cilia grey. Hindwings and cilia grey-whitish.

New South Wales: Maryland, near Stanthorpe, in July and August (W. B. Barnard); three specimens. Type in Queensland Museum.

1758. *PHILOBOTA INCOMPTA*, n. sp. (*incomptus*, undistinguished.)

♂. 25-26 mm. Head and thorax ochreous-whitish sprinkled with grey. Palpi with terminal joint one-half; ochreous-whitish. Abdomen brownish-grey; apices of segments and tuft whitish-ochreous. Forewings narrow, costa gently arched, apex pointed, termen very obliquely rounded; ochreous-whitish finely sprinkled with grey; markings grey; first discal at one-third, second discal before two-thirds, indistinctly double, a dot above and between discals, another before second discal; a slender line from costa before apex, obliquely inwards, angled outwards beneath costa, thence outwardly curved to tornus, sometimes indistinct; a series of minute terminal dots; cilia ochreous-whitish. Hindwings and cilia grey.

Queensland: Crow's Nest, near Toowoomba, in April; two specimens.

1759. *PHILOBOTA BRACHYOMIS* MEYR., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1603. (Katoomba.)

1760. *PHILOBOTA BATHROPHAEA* TURN., *ibid.*, 1914, p. 557. (Ebor.)

1761. *PHILOBOTA ANISOCHROA*, n. sp. (*ἀνισοχρῶς*, unequally coloured.)

♂, ♀. 17-20 mm. Head pale brownish or ochreous. Palpi with second joint just reaching base of antennae, terminal joint two-thirds; ochreous-whitish, second joint except apex fuscous. Antennae fuscous; ciliations in male 1. Thorax pale brownish, in female pale ochreous; tegulae fuscous. Abdomen pale grey. Legs fuscous; posterior pair ochreous-whitish. Forewings narrow, suboval, costa gently arched, apex round-pointed, termen very obliquely rounded; pale brownish, in female pale yellow; a fuscous basal fascia slightly produced on costa and dorsum; usually an elongate fuscous mark on costa slightly beyond middle; sometimes a fuscous dot on costa before apex; cilia pale grey. Hindwings pale grey; cilia ochreous-whitish. The difference in colour between the sexes is unusual.

Queensland: Macpherson Rge. (3,000-4,000 ft.) in November; eight males and three females.

1762.† *PHILOBOTA TRIPLECTIS* MEYR., *Exot. Micro.*, i, p. 123. (Atherton.)

1763. *PHILOBOTA XESTA*, n. sp. (*ἔστος*, polished.)

♂. 30 mm. Head and thorax grey. Palpi with terminal joint three-fifths; grey. Antennae grey; ciliations in male two-thirds. Abdomen dull reddish; tuft ochreous-

whitish. Legs grey; posterior pair ochreous-whitish. Forewings with costa strongly arched, apex obtusely pointed, termen slightly rounded, oblique; glossy grey; costal edge whitish; markings fuscous; first discal at one-third, plical slightly beyond, second discal before two-thirds, double, a dot above and between discals; a fine line from three-fourths costa indented above middle, thence curved to tornus; cilia grey. Hindwings ochreous-grey-whitish; cilia concolorous.

New South Wales: Sydney (National Park) in February; one specimen. Type in Coll. Goldfinch.

1764. *PHILOBOTA ERGATIS* MEYR., PROC. LINN. SOC. N.S.W., 1884, p. 785. = *orphnaea* TURN., *Trans. Roy. Soc. S. Aust.*, 1896, p. 24. (Cairns to Sydney, Macpherson Rge., Katoomba.)

1765.† *PHILOBOTA SYNAUGES* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1622. (Mt. Kosciusko.)

1766.† *PHILOBOTA MELANOPLOCA* MEYR., *ibid.*, 1883, p. 508. (Brisbane.)

1767. *PHILOBOTA VILIS*, n. sp. (*vilis*, valueless.)

♂, ♀. 18–22 mm. Head and thorax pale brownish. Palpi with terminal joint three-fifths; pale fuscous, apex of second joint ochreous-whitish. Antennae pale ochreous-grey with fine fuscous annulations; ciliations in male 2 to 2 and one-half. Abdomen pale brown; apices of segments and tuft ochreous-whitish; in male with a tuft of long ochreous hairs from near base of hindwing beneath. Legs ochreous-whitish; anterior pair fuscous. Forewings with costa moderately arched, apex round-pointed, termen slightly rounded, oblique; pale brownish-grey irrorated with fuscous; discal and sub-terminal dots sometimes minute or absent; first discal at one-fourth, plical beyond it, second discal at three-fifths; a slender line from three-fourths costa, angled above middle, thence slightly curved to tornus, sometimes absent; sometimes a faint line from second discal to tornus; cilia concolorous. Hindwings and cilia pale grey. Nearest *P. ergatis*, from which it differs in the antennal annulations, and in the longer antennal ciliations (in *ergatis*, 1) together with the ventral hair-tuft.

Queensland: Macpherson Rge. (2,500 ft.) in November; Toowoomba in October; thirteen specimens.

1768.† *PHILOBOTA ENNEPHELA* MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 374. (Katoomba, Melbourne.)

1769. *PHILOBOTA HYLOPHILA* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 95. (Mt. Tamborine, Macpherson Rge.)

1770. *PHILOBOTA PHAEOCHYTA*, n. sp. (*φαιοχυτος*, darkly suffused.)

♂. 13–15 mm. Head pale ochreous-grey. Palpi with terminal joint two-fifths; whitish-ochreous, outer surface of second joint fuscous towards base. Antennae fuscous; ciliations in male 1. Thorax fuscous. Abdomen grey. Legs fuscous; tarsi with whitish rings, posterior tibiae grey. Forewings narrow, posteriorly dilated, apex pointed, termen obliquely rounded; whitish-ochreous mostly suffused with fuscous; absence of suffusion leaves an antemedian transverse fascia, and a costal spot at three-fourths not reaching tornus; dark fuscous discal dots, first at one-third, second at middle, plical beneath first; cilia fuscous. Hindwings and cilia pale grey.

Victoria: Mt. Macedon in November (Dr. W. E. Drake); three specimens. Type in National Museum.

1771. *PHILOBOTA MICROSHEMA* MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 173. (Cradle Mt., Mt. Wellington.)

1772. *PHILOBOTA XANTHOCOMA* LOW., *ibid.*, 1897, p. 19. (Adelaide.)

1773. *PHILOBOTA ZOPHOSPILA*, n. sp. (*ζοφοσπιλος*, dark spotted.)

♂. 17 mm. Head and thorax white. Palpi with terminal joint two-thirds; white, basal half of external surface and a subapical ring on second joint dark fuscous. Antennae fuscous; ciliations in male three-fourths. Abdomen grey. Legs fuscous with whitish rings; middle femora and posterior pair mostly whitish. Forewings with costa moderately arched, apex rounded, termen obliquely rounded; white with slight patchy fuscous sprinkling; costal edge near base and markings dark fuscous; a short basal mark from costa; a dot on one-fourth costa; discals approximated, first at one-third, second at three-fifths, plical absent; a large spot on two-thirds costa connected by

suffusion with second discal; a suffused line from costa before apex to tornus; cilia grey-whitish. Hindwings grey; cilia grey-whitish with a darker sub-basal line.

North Queensland: Babinda, near Innisfail, in September; one specimen.

1774. *PHILOBOTA STENOSEMA*, n. sp. (*στενοσημος*, slenderly marked.)

♂, ♀. 15-16 mm. Head and thorax white. Palpi with terminal joint three-fifths; whitish, second joint except apex fuscous. Antennae grey, basal joint white; ciliations in male 1 and one-half. Abdomen grey. Legs whitish; anterior pair fuscous. Forewings with costa moderately arched, apex pointed, termen very oblique; white; markings fuscous; a basal fascia; an inwardly curved interrupted line from three-fifths costa to two-fifths dorsum; a second line from three-fifths costa to tornus; a costal spot before apex; cilia white. Hindwings and cilia grey.

Queensland: Yeppoon in August (W. B. Barnard); two specimens. Type in Queensland Museum.

1775. *PHILOBOTA OCCIDUA* MEYR., *Proc. Linn. Soc. N.S.W.*, 1883, p. 507. (Tweed Hds. to Lorne, Stanthorpe, Glen Innes, Bathurst, Mittagong, Hobart, Denmark.)

1776. *PHILOBOTA GRAPHICA* MEYR., *Proc. Linn. Soc. N.S.W.*, 1887, p. 951. (Warragul, Broken Hill, Pt. Lincoln.)

1777. *PHILOBOTA CARDINALIS* MEYR., *Exot. Micro.*, i, p. 131. (Vict.: Beaconsfield.)

1778. *PHILOBOTA METRIA* TURN., *Trans. Roy. Soc. Aust.*, 1917, p. 91. (Gisborne.)

1779. *PHILOBOTA METARGA* TURN., *Proc. Roy. Soc. Tasm.*, 1938, p. 95. (Hobart, Mt. Wellington.)

1780. *PHILOBOTA ORESTERA* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 93. (Mt. Kosciusko, 7,000 ft.)

1781.† *PHILOBOTA LIMENARCHA* MEYR., *Exot. Micro.*, i, p. 123. (Atherton.)

1782.† *PHILOBOTA OXYSEMA* LOW., *Trans. Roy. Soc. S. Aust.*, 1903, p. 223. (Broken Hill.)

1783. *PHILOBOTA ISOMORA* TURN., *Proc. Linn. Soc. N.S.W.*, 1915, p. 193. (Ebor.)

1784. *PHILOBOTA ORTHOMITA* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 88. = *picraula* Low., *ibid.*, 1920, p. 63. (Gisborne, Hobart, Mt. Lofty.)

1785. *PHILOBOTA MYSTICODES* TURN., *ibid.*, 1917, p. 84. (Brisbane.)

1786. *PHILOBOTA CROCOCEPHALA*, n. sp. (*κροκωκεφαλος*, saffron-headed.)

♂. 18 mm. Head and thorax orange. Palpi with terminal joint two-thirds; whitish, middle of outer surface of second joint fuscous. Abdomen grey; tuft whitish. Forewings posteriorly dilated, costa moderately arched, apex round-pointed, termen very obliquely rounded; whitish; a basal orange fascia shortly produced on costa; cilia whitish. Hindwings and cilia pale grey.

West Australia: Denmark in November; one specimen.

1787.† *PHILOBOTA EUTELOPIS* MEYR., *Exot. Micro.*, ii, p. 384. (Townsville, Brisbane.)

1788. *PHILOBOTA DOLICOTHRIX* TURN., *Proc. Roy. Soc. Tasm.*, 1938, p. 96. (Tasman Peninsula, Strahan.)

1789.† *PHILOBOTA OTIOSA* MEYR., *Exot. Micro.*, ii, p. 385. (Brisbane.)

1790. *PHILOBOTA BASILIS* TURN., *Proc. Roy. Soc. Tasm.*, 1926, p. 152. (Hobart.)

1791. *PHILOBOTA POLIOCNECA* TURN., *ibid.*, 1926, p. 153. (Cradle Mt.)

1792. *PHILOBOTA PULVEREA* MEYR., *Proc. Linn. Soc. N.S.W.*, 1883, p. 509. (Brisbane to Gisborne, Ebor.)

1793. *PHILOBOTA EGELIDA* MEYR., *ibid.*, 1883, p. 374. (Tweed Hds., Sydney.)

1794. *PHILOBOTA CHIONOLEUCA*, n. sp. (*χιονολευκος*, snow-white.)

♀. 22 mm. Head white. Palpi with terminal joint three-fifths; white, second joint except apex grey. Antennae grey, towards base white. Thorax pale grey. Abdomen white. Legs white; anterior pair fuscous. Forewings narrow, costa almost straight, apex pointed, termen slightly rounded, strongly oblique; shining white; a broadly suffused pale grey streak from base to apex on dorsum; cilia white, on tornus pale grey. Hindwings grey-whitish; cilia whitish.

Queensland: Macpherson Rge. (Springbrook) in November; one specimen.

1795. *PHILOBOTA NOTOMOLYBDA*, n. sp. (*νοτομολυβδος*, with leaden-grey dorsum.)

♂. 26 mm. Head and thorax pale leaden-grey. Palpi with terminal joint three-fifths; whitish, second joint except apex grey. Antennae grey; ciliations in male 1

and a half. Abdomen grey. Legs grey; posterior pair whitish. Forewings with costa gently arched, apex round-pointed, termen obliquely rounded; white; costal edge dark fuscous towards base; a broad leaden-grey dorsal suffusion from base to tornus; cilia pale grey, on apex white. Hindwings and cilia pale grey.

New South Wales: Mt. Kosciusko in December; one specimen. Type in Coll. Goldfinch.

1796. *PHILOBOTA CASTA* Turn., *Proc. Roy. Soc. Tasm.*, 1938, p. 97. (Mt. Wellington.)

1797. *PHILOBOTA IMMÉMOR* Meyr., *Exot. Micro.*, i, p. 130. (Townsville.)

1798. *PHILOBOTA EUAGETA*, n. sp. (εὐαγητος, pure.)

♂. 23 mm. Head and thorax white. Palpi with terminal joint one-half; white. Antennae fuscous; ciliations of male extremely long (10). Abdomen grey; tuft white. Legs white; anterior pair fuscous. Forewings rather narrow, costa gently arched, apex rounded, termen slightly rounded, oblique; shining white; costal edge towards base dark fuscous; stigmata minute, fuscous, first discal at one-third, plical beyond it, second discal at two-thirds, indistinctly double; cilia white. Hindwings and cilia grey-whitish.

Victoria: Mt. Buffalo in February; one specimen.

1799. *PHILOBOTA NOTIODES*, n. sp. (νοτιωδης, moist.)

♂. 21-22 mm. Head ochreous. Palpi with terminal joint three-fifths; fuscous, terminal joint and apex of second whitish. Antennae grey with dark fuscous annulations; ciliations in male 1. Thorax grey-whitish. Abdomen dark grey; tuft ochreous-whitish. Legs fuscous with ochreous-whitish rings. Forewings elongate, costa slightly arched, apex pointed, termen very obliquely rounded; pale glossy grey; costa and termen narrowly ochreous-tinged; base narrowly fuscous; cilia ochreous-whitish. Hindwings grey; cilia whitish-ochreous.

New South Wales: Ebor in December; two specimens.

1800. *PHILOBOTA CATHAROPA*, n. sp. (καθαρωπος, spotless.)

♀. 32 mm. Head and thorax white. Palpi with terminal joint three-fifths; white. Antennae white. Abdomen grey; apices of segments and tuft white. Legs white; anterior pair grey-whitish. Forewings narrow, costa moderately arched, apex round-pointed, termen very obliquely rounded; shining white; cilia white. Hindwings and cilia grey-whitish. Considerably larger than *P. euageta*, the palpi rather longer, forewings with 2 and 3 almost connate, 7 and 8 forked at one-third of their length, and without markings. In *P. euageta* 2 and 3 are separate, and 7 and 8 are stalked at three-fourths of their length near termen.

Queensland: Injune in February (W. B. Barnard); one specimen.

1801. *PHILOBOTA CENTROMITA*, n. sp. (κεντρομιτος, with central thread.)

♂. 24-25 mm. Head and thorax whitish-brown. Palpi with terminal joint three-fifths; whitish, outer surface of second joint except apex grey. Antennae grey; ciliations in male 3. Abdomen pale grey; tuft ochreous-whitish. Forewings elongate, costa gently arched, apex pointed, termen very obliquely rounded; whitish-brown; a pale fuscous streak slightly above middle from base to three-fifths; stigmata minute, fuscous, first discal at two-fifths on lower edge of streak, second at three-fifths on upper edge; cilia whitish. Hindwings and cilia pale grey.

Queensland: Bunya Mts. in April (W. B. Barnard); two specimens. Type in Queensland Museum.

1802. *PHILOBOTA AMBLYS*, n. sp. (ἀμβλυς, faint.)

♂. 22-24 mm. Head pale brownish. Palpi with terminal joint one-half; brownish. Antennae whitish-brown with dark fuscous annulations; ciliations in male 3. Thorax fuscous-brown. Abdomen whitish-grey, darker towards base. Legs fuscous; posterior pair ochreous-whitish. Forewings elongate, costa moderately arched, apex pointed, termen very obliquely rounded; brown-whitish with some fuscous sprinkling mostly in mid-disc and beneath basal two-thirds of costa; stigmata minute, fuscous, sometimes partly obsolete, first discal before one-third, plical beyond it, second discal before two-thirds, a dot above and between discals; minute fuscous terminal dots; cilia whitish. Hindwings and cilia grey-whitish.

Queensland: Yeppoon in June; four specimens.

1803. *PHILOBOTA AMELES*, n. sp. (*ἀμελης*, uncared for.)

♂. 21-22 mm. Head and thorax fuscous. Palpi with terminal joint one-half; fuscous. Antennae grey with fuscous annulations; ciliations in male 3. Abdomen grey; tuft grey-whitish. Forewings elongate, costa gently arched, apex pointed, termen obliquely rounded; grey sprinkled with fuscous and sometimes a few whitish scales; stigmata minute, fuscous, first discal at one-fourth, plical slightly beyond, second discal about middle, a dot above and between discals; some fuscous terminal dots; cilia grey. Hindwings and cilia pale grey.

Queensland: Noosa in May; two specimens.

1804. *PHILOBOTA AMBLOPIS*, n. sp. (*ἀμβλωπις*, obscure.)

♂, ♀. 25 mm. Head and thorax fuscous. Palpi with terminal joint one-half; fuscous. Antennae grey with fuscous annulations; ciliations in male 4. Abdomen grey; tuft whitish-ochreous. Legs fuscous; posterior pair whitish-ochreous. Forewings elongate, costa slightly arched, apex pointed, termen very obliquely rounded; grey finely sprinkled with fuscous; stigmata obscure, minute, fuscous, first discal at one-third, second at two-thirds; cilia grey. Hindwings and cilia pale grey. Differs from *P. ameles* in absence of terminal dots on forewings.

Queensland: Injune in May (W. B. Barnard); two specimens. Type in Queensland Museum.

1805. *PHILOBOTA OCHRONOTA*, n. sp. (*ὀχρονωτος*, with pale dorsum.)

♂. 15 mm. Head fuscous; face whitish. Palpi with terminal joint one-half; fuscous, extreme apices of second and terminal joints whitish. Antennae grey; ciliations in male 1 and one-half. Thorax and abdomen fuscous; tuft whitish. Forewings narrow, costa gently arched, apex pointed, termen very obliquely rounded; fuscous; a broad grey-whitish dorsal streak from base nearly to tornus, with a slight angular median projection; stigmata obscure, dark fuscous, first discal at one-third, plical beyond it, second discal before two-thirds, a dot above and between discals; a whitish dot beneath second discal. Hindwings and cilia grey.

West Australia: Albany in March (W. B. Barnard); one specimen.

1806. *PHILOBOTA OCHROSTICTA*, n. sp. (*ὀχροστικτος*, pale-speckled.)

♂. 15-18 mm. Head and thorax fuscous. Palpi with terminal joint one-half; fuscous, extreme apices of second and terminal joints whitish. Antennae fuscous; ciliations in male 1 and one-half. Abdomen grey; tuft grey-whitish. Legs fuscous; tarsi with whitish rings; posterior pair grey-whitish. Forewings narrow, costa slightly arched, apex pointed, termen very obliquely rounded; fuscous finely sprinkled with whitish; stigmata dark fuscous, first discal at one-fourth, plical beyond it, second discal about middle, a dot above and between discals; minute whitish dots before plical and beneath second discal; cilia fuscous. Hindwings and cilia grey.

Queensland: Macpherson Rge. in November. New South Wales: Glen Innes in March. Three specimens.

1807. *PHILOBOTA PARASEMA* Low., *Trans. Roy. Soc. S. Aust.*, 1920, p. 63. I have examined the type, which is a male expanding 19 mm.; the palpi are missing; the antennal ciliations two-thirds; the whitish costal edge of forewings is an optical delusion. (Adelaide.)

1808.† *PHILOBOTA CRUSTULATA* Meyr., *Exot. Micro.*, i, p. 124. (W. Aust.: Waterloo.)

1809.† *PHILOBOTA ORIPHAEA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1888, p. 1613. (Mt. Kosciusko.)

1810. *PHILOBOTA MODESTA*, n. sp. (*modestus*, unpretentious.)

♂. 18 mm. Head and thorax fuscous. Palpi with terminal joint two-thirds; whitish outer surface of second joint except apex fuscous. Antennae grey; ciliations in male slightly over 1. Abdomen grey. Legs fuscous; posterior pair grey-whitish. Forewings with costa slightly arched, apex round-pointed, termen nearly straight, slightly oblique; grey-whitish sprinkled with grey; discals fuscous, minute, approximated, first discal at one-fourth, second at about middle; cilia grey. Hindwings and cilia pale grey.

Queensland: Killarney in January (W. B. Barnard); one specimen.

1811. *PHILOBOTA DELOSTICTA*, n. sp. (*δηλοστικτος*, distinctly spotted.)

♂. 20–25 mm. Head grey-whitish. Palpi with terminal joint three-fifths; grey-whitish, basal half or more of outer surface of second joint fuscous. Antennae grey; ciliations in male 2. Thorax and abdomen grey. Legs fuscous with whitish rings; posterior pair grey-whitish. Forewings sub-oblong, costa slightly arched, apex rectangular, termen slightly rounded, scarcely oblique; grey lightly but evenly sprinkled with dark fuscous; markings dark fuscous; a basal costal dot; stigmata approximated, very distinct, first discal at two-fifths, plical beyond it, second discal at three-fifths; an interrupted subterminal line indented beneath costa; cilia grey. Hindwings grey; cilia grey-whitish with darker basal line.

North Queensland: Cape York in October (W. B. Barnard); five specimens. Type in Queensland Museum.

1812. *PHILOBOTA EUCHRYSA* Low., *Trans. Roy. Soc. S. Aust.*, 1894, p. 99. (Townsville to Brisbane, Stanthorpe, Dalby, Cunnamulla.)

1813. *PHILOBOTA CATOPTRINA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1884, p. 776. *Gen. Ins. Oecoph.*, Pl. 4, f. 63. (Caloundra, Sydney.)

1814. *PHILOBOTA IOPLACA*, n. sp. (*ιοπλακος*, with a violet blotch.)

♂, ♀. 17–18 mm. Head ochreous. Palpi with terminal joint one-half; whitish, outer surface of second joint sprinkled with fuscous. Antennae grey with dark fuscous annulations; ciliations in male 1. Thorax yellow, anterior border fuscous. Abdomen grey; apices of segments and tuft pale ochreous. Legs fuscous with whitish rings; posterior pair whitish. Forewings moderately arched, apex subrectangular, termen obliquely rounded; yellow; a pale violet terminal blotch, edged anteriorly by a slender irregular fuscous line from near apex to two-thirds dorsum, posteriorly and superiorly by a broader line irregularly suffused; cilia grey; apices whitish. Hindwings grey; cilia whitish.

North Queensland: Cape York in April (W. B. Barnard); seven specimens. Type in Queensland Museum.

1815. *PHILOBOTA TENTATELLA* Wlk., xxix, p. 685. Meyr., *Proc. Linn. Soc. N.S.W.*, 1883, p. 507. (Cape York to Lismore, Katoomba, Milmerran.)

1816. *PHILOBOTA EPIDESMA* Meyr., *ibid.*, 1885, p. 532. (Cairns, Duaranga.)

1817. *PHILOBOTA EUCTISTA* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 92. (Atherton.)

1818. *PHILOBOTA PHAEOCEPHALA* Turn., *ibid.*, 1917, p. 69. (Brisbane.)

1819. *PHILOBOTA BOTRYITIS* Meyr., *Exot. Micro.*, i, p. 245 (1914). = *euryzona* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 69. (Brisbane, Tweed Hds.)

1820. *PHILOBOTA INITIATA* Meyr., *Exot. Micro.*, ii, p. 382. (S. Aust.: Pinnaroo, Owen.)

1821. *PHILOBOTA EPIPLASTA* Turn., *Trans. Roy. Soc. S. Aust.*, 1917, p. 70. (Cairns, Atherton.)

1822. *PHILOBOTA ACROPLACA*, n. sp. (*ακροπλακος*, with apical blotch.)

♂, ♀. 14–16 mm. Head orange-yellow. Palpi with terminal joint two-fifths; pale yellow, basal and subapical rings on second and terminal joints fuscous. Antennae fuscous; ciliations in male 1. Thorax dark fuscous. Abdomen grey. Legs fuscous with whitish rings; posterior pair except tarsi whitish-ochreous. Forewings with costa gently arched, apex rectangular, termen sinuate, scarcely oblique; yellow; a small straight-edged fuscous basal fascia; a fuscous-purple apical blotch, edged by a wavy fuscous line from three-fifths costa to three-fifths dorsum; cilia ochreous-grey, apices whitish. Hindwings and cilia grey.

North Queensland: Cape York in April, May and June (W. B. Barnard); eleven specimens. Type in Queensland Museum.

1823. *PHILOBOTA SPECTABILIS* Turn., *Trans. Roy. Soc. S. Aust.*, 1896, p. 28. (Brisbane.)

1824. *PHILOBOTA TERPNOPIΣ*, n. sp. (*τερπνωπις*, pleasing.)

♂. 13–15 mm. Head yellow. Palpi with terminal joint two-thirds; pale yellow, outer surface of second joint fuscous towards base. Antennae fuscous; ciliations in male 1. Thorax yellow, anterior edge fuscous. Abdomen grey; tuft whitish-ochreous. Legs fuscous; posterior pair grey. Forewings narrow, costa gently arched, apex pointed, termen oblique; yellow with fuscous markings; a costal streak from base to one-third;

a costal triangle on three-fifths costa, produced at apex so as almost to meet a triangular mark from tornus; some fuscous sprinkling between this and termen; sometimes a terminal line; cilia yellow. Hindwings and cilia dark grey.

New South Wales: Sydney (National Park) in April; Bulli in October (G. M. Goldfinch); three specimens. Type in Australian Museum.

1825. *PHILOBOTA DILECHRIA*, n. sp. (*διλεχριος*, twice oblique.)

♂. 14–22 mm. Head yellow. Palpi with terminal joint three-fifths; pale yellow, outer surface of second joint except apex fuscous. Antennae grey; ciliations in male long (5 to 6). Thorax fuscous; patagia yellow. Abdomen fuscous; tuft yellow. Legs fuscous; posterior pair ochreous-whitish. Forewings narrow, posteriorly dilated, costa straight to beyond middle, thence slightly arched, apex pointed, termen straight, oblique; yellow with fuscous markings; a broad costal streak from base, narrowing to two-thirds; a narrow subterminal fascia, broadening on dorsum, where it extends from two-thirds to tornus; a terminal line; cilia fuscous. Hindwings and cilia fuscous.

North Queensland: Palm I., a number seen flying in sunlight soon after sunrise among grass near high-water mark on 31st May; also one from Frankston, near Cairns, in National Museum.

1826. *PHILOBOTA MENODORA* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1657. (Adelaide, Geraldton.)

1827. *PHILOBOTA OCELLARIS* MEYR., *ibid.*, 1884, p. 773. (Tweed Hds., Newcastle, Sydney, Katoomba, Melbourne, Mt. Lofty.)

1828. *PHILOBOTA ANNULARIS* MEYR., *ibid.*, 1884, p. 774. = *athletica* Rosen, *Ann. Mag. Nat. Hist.*, 1885, p. 443. (Melbourne.)

1829.† *PHILOBOTA CONCISELLA* Wlk., xxix, p. 678. (Katoomba.)

1830. *PHILOBOTA CROCODES*, n. sp. (*κροκωδης*, saffron-coloured.)

♂. 20 mm. Head orange-yellow. Palpi with terminal joint two-fifths; fuscous, terminal joint and apex of second whitish-ochreous. Antennae fuscous; ciliations in male 1. Thorax fuscous. (Abdomen missing.) Legs fuscous; posterior pair pale ochreous. Forewings narrow, costa straight to two-thirds, thence gently arched, apex rounded, termen nearly straight, oblique; orange-yellow; markings fuscous; a basal fascia projecting on costa and above dorsum; a narrow inwardly curved fascia from two-thirds costa to tornus; a terminal fascia broader towards apex; cilia fuscous. Hindwings and cilia fuscous.

Queensland: Milmerran in November; one specimen received from Mr. J. Macqueen.

1831. *PHILOBOTA ZANCLOTOMA* MEYR., PROC. LINN. SOC. N.S.W., 1884, p. 773. (Bathurst, Moe, Adelaide, Mt. Lofty.)

1832.† *PHILOBOTA HEMERIS* MEYR., *Exot. Micro.*, i, p. 303. (Duaringa.)

1833. *PHILOBOTA ACROTROPA* MEYR., PROC. LINN. SOC. N.S.W., 1884, p. 779. (Sydney.)

1834. *PHILOBOTA SOBRINA*, n. sp. (*sobrinus*, a cousin.)

♂. 16 mm. Head pale yellow. Palpi with terminal joint two-thirds, outer surface of second joint grey towards base. Antennae fuscous; ciliations of male very short (one-fourth). Thorax fuscous. Abdomen grey; tuft ochreous-tinged. Legs pale ochreous; anterior pair fuscous. Forewings suboval, costa moderately arched, apex rounded, termen obliquely rounded; yellow; a pale fuscous costal streak from base to middle; a purple-fuscous terminal band, sharply defined by a line from three-fourths costa to three-fourths dorsum; cilia grey. Hindwings and cilia grey. Resembles *P. acrotropa*, but differs in the short antennal ciliations, the longer terminal joint of palpi (in *acrotropa* one-half), and differently shaped terminal band of forewings.

Queensland: Injune in February (W. B. Barnard).

1835. *PHILOBOTA STENOTYPA* TURN., *Trans. Roy. Soc. S. Aust.*, 1917, p. 72. (Ebor.)

1836. *PHILOBOTA PARACYCLA* MEYR., PROC. LINN. SOC. N.S.W., 1884, p. 777. (Marmor to Melbourne, Stanthorpe, Bathurst, Injune, Mt. Lofty, West Australia.)

1837.† *PHILOBOTA APHANES* MEYR., *ibid.*, 1884, p. 782. (Murrurundi.)

1838. *PHILOBOTA XANTHIELLA* Wlk., xxix, p. 693. MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 505. (Nambour to Melbourne, Ebor, Katoomba, Bathurst, Hobart, Mt. Lofty, Waroona, Perth.)

1839. *PHILOBOTA AURINATELLA* Wlk., xxix, p. 693. MEYR., PROC. LINN. SOC. N.S.W., 1883, p. 504. (Caloundra to Gisborne, Ebor, Katoomba, Mt. Kosciusko, Mt. Buffalo, Tasmania.)

1840.† *PHILOBOTA ARCHESCIA* MEYR., *ibid.*, 1887, p. 932. (Geraldton.)

1841.† *PHILOBOTA AUXOSCIA* MEYR., *Exot. Micro.*, ii, p. 512. (Gisborne.)

1842. *PHILOBOTA CURRICULATA* MEYR., *ibid.*, ii, p. 384. (Westwood, Eidsvold, Dalby, Injune.)

1843. *PHILOBOTA POLIOCROSSA*, n. sp. (*πολιοκροσσος*, grey-edged.)

♂. 18 mm. Head and thorax pale yellow. Palpi with terminal joint two-thirds; pale yellow. Antennae grey; ciliations in male one-half. Abdomen grey; tuft ochreous. Forewings narrow, costa slightly arched, apex rounded, termen very obliquely rounded; pale yellow; a fuscous spot on termen; an apical fuscous spot prolonged as a line to tornus; cilia grey, on apex fuscous. Hindwings and cilia grey. Best distinguished from *P. curriculata* by its yellow thorax.

Queensland: Injune in March (W. B. Barnard); one specimen.

1844. *PHILOBOTA HEMICROCA* LOW., *Trans. Roy. Soc. S. Aust.*, 1903, p. 223. (Stawell, Gisborne.)

1845.† *PHILOBOTA CIRRHODES* MEYR., *Exot. Micro.*, i, p. 126. (Tasm.: Derby.)

1846. *PHILOBOTA STIPULATA* MEYR., *ibid.*, i, p. 119. (Darwin.)

1847. *PHILOBOTA AETOPIS* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1627. (Victoria, Mt. Lofty, West Australia.)

1848. *PHILOBOTA MONOPHAES* MEYR., *ibid.*, 1883, p. 504. (Katoomba, Melbourne.)

1849. *PHILOBOTA SYMBLETA* TURN., *ibid.*, 1914, p. 556. (Ebor.)

1850.† *PHILOBOTA SCIOCROSSA* MEYR., *Exot. Micro.*, i, p. 119. (Darwin.)

1851. *PHILOBOTA CAMINIAS* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1624. (Mt. Lofty, West Australia.)

1852. *PHILOBOTA CAUSTA*, n. sp. (*καυστος*, scorched.)

♂, ♀. 16–22 mm. Head ochreous. Palpi with terminal joint one-half in male, two-fifths in female; whitish, outer surface of second joint except apex fuscous. Antennae fuscous; ciliations in male two-thirds. Thorax and abdomen fuscous. Legs fuscous; posterior pair ochreous-whitish. Forewings narrow, costa slightly arched, apex rounded, termen obliquely rounded; dark reddish-brown, in female paler; cilia grey. Hindwings and cilia grey.

Queensland: Injune in October and April (W. B. Barnard); four specimens. Type in Queensland Museum.

1853. *PHILOBOTA SEMIFULVA*, n. sp. (*semifulvus*, half brownish.)

♂. 22 mm. Head whitish-ochreous. Palpi with terminal joint one-half; pale grey. Antennae grey; ciliations in male long (5 to 6). Thorax dark fuscous. Abdomen grey; apices of segments and tuft ochreous. Legs ochreous; anterior pair grey. Forewings elongate, costa slightly arched, apex rounded, termen straight; oblique; pale yellow; base narrowly fuscous; posterior to a line from one-third costa to mid-dorsum brown; sharply defined anteriorly, posteriorly containing some ochreous suffusion; cilia brown. Hindwings and cilia pale brownish.

New South Wales: Murrurundi in March; two specimens received from Dr. B. L. Middleton.

1854. *PHILOBOTA HETEROPHAEA*, n. sp. (*ἑτεροφαιος*, variably dusky.)

♂. 17–20 mm. ♀. 22–24 mm. Head yellow. Palpi with second joint exceeding base of antennae, terminal joint three-fifths; yellowish, second joint fuscous on external surface except at apex; in some examples terminal joint partly suffused with fuscous. Antennae dark fuscous; ciliations in male 1 and one-half. Thorax yellow; patagia sometimes fuscous; rarely wholly fuscous. Abdomen dark grey; tuft pale ochreous-grey. Forewings rather narrow, not dilated, costa gently arched, apex round-pointed, termen obliquely rounded; yellow with dark fuscous markings; sometimes much and occasionally altogether suffused with dark fuscous; a broad costal streak to one-fourth; first discal at one-third, second before two-thirds, both connected with a broadly suffused inwardly oblique streak from costa beyond middle; plical beyond first discal, sometimes lost in suffusion; an apical blotch giving rise to a terminal fascia, which is sometimes very

broadly suffused; cilia fuscous, apices sometimes pale yellowish. Hindwings and cilia grey.

Extremely variable; in some examples the forewings are yellow with markings very distinct, in others these are more or less broadly suffused and confluent, leaving only the base or dorsum yellow; occasionally the forewings are almost entirely fuscous.

Queensland: Macpherson Rge. (2,500–3,500 ft.) in December and January; locally abundant.

1855. *PHILOBOTA DEJUNCTELLA* Wlk., xxx, p. 1036. MEYR., PROC. LINN. SOC. N.S.W., 1882, p. 452. (Caloundra to Melbourne, Katoomba, Launceston, Adelaide, Kangaroo I., West Australia.)

1856. *PHILOBOTA ANTHOPHORA*, n. sp. (*ἀνθοφορος*, flowery.)

♂. 16 mm. Head and thorax pale yellow. Palpi with terminal joint one-half; pale yellow. Antennae grey; ciliations in male 1. Abdomen whitish-grey; tuft whitish. Legs rosy; posterior pair ochreous-whitish. Forewings with costa moderately arched, apex rounded, termen obliquely rounded; yellow; costal edge fuscous to one-eighth, thence white to apex; a subcostal line, a streak on dorsum to one-third, and terminal edge rosy; cilia rosy, apices whitish. Hindwings and cilia whitish.

West Australia: Denmark in March (W. B. Barnard); one specimen.

1857. *PHILOBOTA PYRRHOPHARA*, n. sp. (*πυρρόφαρος*, in reddish clothing.)

♂. 16 mm. Head and thorax reddish. Palpi with terminal joint slightly exceeding one-half; fuscous, inner surface and terminal joint grey-whitish. Antennae grey-whitish; ciliations in male 1. Abdomen whitish-ochreous. Legs fuscous; posterior pair whitish-ochreous. Forewings dilated posteriorly, costa gently arched, apex subrectangular, termen rounded, slightly oblique; dull reddish or rosy with sparsely scattered fuscous scales; a fuscous dot in disc at two-thirds and another at three-fifths; cilia reddish. Hindwings and cilia whitish-grey.

Queensland: Macpherson Rge. (2,500 ft.) in open forest in November; two specimens.

1858. *PHILOBOTA CALAMOCHROA*, n. sp. (*καλαμοχρως*, straw-coloured.)

♂. 16 mm. Head and thorax whitish-ochreous. Palpi with terminal joint one-half; whitish, outer surface of second joint except apex fuscous. Antennae pale grey; in male serrulate, ciliations 1 and one-half. Abdomen pale grey; apices of segments and tuft white. Legs whitish; anterior pair fuscous. Forewings narrow, posteriorly dilated, costa moderately arched, apex obtusely pointed, termen nearly straight, oblique; pale brownish-ochreous; costal edge towards base dark fuscous; a minute discal dot at two-thirds; slight fuscous suffusion between this and tornus; cilia concolorous. Hindwings and cilia whitish.

Queensland: Macpherson Rge. (2,500 ft.) in November; one specimen.

1859. *PHILOBOTA MALACOPIS* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1643. (Wallaroo, Carnarvon.)

1860. *PHILOBOTA METACHROA* MEYR., *ibid.*, 1888, p. 1616. (Mt. Kosciusko, Mt. Buffalo, Cradle Mt.)

1861. *PHILOBOTA OMOTYPA*, n. sp. (*ὠμοτύπος*, shoulder-marked.)

♂. 20–23 mm. Head yellow. Palpi with terminal joint two-thirds; pale ochreous, outer surface of second joint except apex fuscous. Antennae fuscous; ciliations in male 1 and one-half. Thorax yellow, anterior half fuscous. Abdomen pale grey. Legs fuscous; posterior pair ochreous-whitish. Forewings narrow, suboval, costa gently arched, apex round-pointed, termen very obliquely rounded; yellow; a dark fuscous costal streak from base to one-fifth; cilia yellow. Hindwings and cilia whitish-grey.

Queensland: Macpherson Rge. in November (W. B. Barnard); five specimens. Type in Queensland Museum.

1862. *PHILOBOTA HOLOCROSSA* MEYR., PROC. LINN. SOC. N.S.W., 1888, p. 1616. (W. Aust.: York.)

1863.† *PHILOBOTA CONIORTIA* MEYR., *ibid.*, 1884, p. 725. (Sydney.)

1864. *PHILOBOTA ACOMPSA*, n. sp. (*ἀκομψος*, unadorned.)

♀. 14–15 mm. Head orange. Palpi with terminal joint three-fifths; whitish sprinkled with fuscous. Antennae grey. Thorax yellow. Abdomen grey. Legs fuscous; posterior pair ochreous-whitish. Forewings suboval, costa gently arched, apex rounded,

termen obliquely rounded; deep yellow; cilia pale yellow. Hindwings dark grey; cilia grey-whitish, on tornus and dorsum grey.

North Queensland: Cape York in April and June (W. B. Barnard); two specimens. Type in Queensland Museum.

1865. *PHILOBOTA MELICHRODES* Turn., *Trans. Roy. Soc. S. Aust.*, 1898, p. 209. (Atherton, Nambour to Sydney, Stanthorpe.)

1866. *PHILOBOTA CINETICA* Meyr., *Proc. Linn. Soc. N.S.W.*, 1884, p. 738. (Atherton, Carnarvon Rge., Toowoomba to Melbourne, Katoomba, Hobart, Mt. Lofty.)

1867. *PHILOBOTA CIRRHOPHARA* Turn., *Proc. Roy. Soc. Tasm.*, 1926, p. 154. = *fulvella* Turn., *ibid.*, 1938, p. 96. (Zeehan, Rosebery, Strahan.)

1868.† *PHILOBOTA LIMONIA* Meyr., *Exot. Micro.*, i, p. 125. (Toowoomba, Glen Innes.)

1869.† *PHILOBOTA APLASTA* Meyr., *ibid.*, i, p. 249. (Carnarvon.)

1870.† *PHILOBOTA MICROCHLORA* Meyr., *ibid.*, i, p. 303. (Darwin.)

1871.† *PHILOBOTA VERA* Meyr., *ibid.*, i, p. 250. (Darwin.)

1872. *PHILOBOTA GERAEOPA* Meyr., *ibid.*, i, p. 118. (Perth.)

1873.† *PHILOBOTA INNOCENS* Meyr., *ibid.*, i, p. 118. (Atherton.)

1874.† *PHILOBOTA IGNAVA* Meyr., *ibid.*, i, p. 125. (Darwin.)

#### Alphabetical List of the Species of *Philobota*.

*acompsa* (1864), *acropalca* (1822), *acropola* (1716), *acrotropa* (1833), *aedophanes* (1732), *aetopis* (1847), *agrapha* (1645), *allocota* (1696), *alloea* (1655), *amalodes* (1646), *amblopis* (1804), *amblys* (1802), *amechana* (1703), *ameles* (1803), *amoebaea* (1675), *amphityca* (1742), *amphitoxa* (1672), *anarrecta* (1691), *ancylotoxa* (1633), *anisochroa* (1761), *annularis* (1828), *anthophora* (1856), *antipodella* (1647), *aphanes* (1837), *aplasta* (1869), *arabella* (1631), *archedora* (1701), *archescia* (1840), *atmobola* (1748), *auantis* (1692), *auriceps* (1630), *aurinatella* (1839), *auxolyca* (1746), *auxoscia* (1841), *axiota* (1750), *bathrophaea* (1760), *biophora* (1632), *borborodes* (1641), *botryitis* (1819), *bracteata* (1705), *brachyomis* (1759), *calamochroa* (1858), *caminiis* (1851), *camptosema* (1689), *campylosema* (1673), *cardinalis* (1777), *casta* (1796), *catalampra* (1640), *catascia* (1637), *catharopa* (1800), *catoptrina* (1813), *causta* (1852), *centromita* (1801), *ceratochroa* (1642), *charaxias* (1661), *chiastis* (1678), *chionoleuca* (1794), *cinetica* (1866), *cirrhodes* (1845), *cirrhophara* (1867), *concisella* (1829), *coniodes* (1757), *coniortia* (1863), *contentella* (1684), *crococephala* (1786), *crocodes* (1830), *crocoptera* (1667), *crustulata* (1808), *crypsichola* (1651), *crypsileuca* (1638), *curriculata* (1842), *dasygopa* (1695), *dejunctella* (1855), *delosema* (1690), *delosticta* (1811), *diffusa* (1737), *dilechria* (1825), *dimochla* (1688), *disema* (1740), *dolichothrix* (1788), *ecclata* (1725), *echidnias* (1676), *egelida* (1793), *ennephela* (1768), *epidesma* (1816), *epiplasta* (1821), *epitoxa* (1671), *ergatis* (1764), *eriscota* (1700), *euageta* (1798), *euarmosta* (1668), *euchrysa* (1812), *euctista* (1817), *eudela* (1662), *euneta* (1729), *eurytoxa* (1666), *eutelopis* (1787), *gephyrodes* (1715), *geraeopa* (1872), *goniotypa* (1664), *gonosema* (1710), *grammophora* (1682), *graphica* (1776), *gymnastica* (1677), *habrodes* (1714), *habrosema* (1693), *hapala* (1739), *hemeris* (1832), *hemicroca* (1844), *heterophaea* (1854), *hiracistis* (1724), *holocrossa* (1862), *hydara* (1753), *hytophila* (1769), *hyphanta* (1665), *hypocausta* (1650), *ignava* (1874), *immemor* (1797), *impletella* (1685), *incompta* (1758), *iniata* (1820), *innocens* (1873), *interlineatella* (1709), *intricata* (1736), *ioplaca* (1814), *iphigenes* (1727), *irruptella* (1634), *isolitha* (1644), *isomora* (1783), *lathicentra* (1708), *latifissella* (1649), *leptomita* (1686), *leucomitra* (1745), *leucozancla* (1663), *limenarcha* (1781), *limonia* (1868), *lochitis* (1697), *lochmaula* (1743), *lonchota* (1653), *lysziona* (1660), *maculopa* (1694), *madida* (1719), *malacopis* (1859), *mechanica* (1681), *megalocentra* (1707), *melanoglypta* (1734), *melanoploca* (1766), *melanozantha* (1658), *melichrodes* (1865), *menodora* (1826), *mesodesma* (1704), *metachroa* (1860), *metacneca* (1747), *metarga* (1779), *metria* (1778), *microchlora* (1870), *microschema* (1771), *microzantha* (1659), *mitoloma* (1657), *modesta* (1810), *monoloncha* (1648), *monolitha* (1643), *monophaes* (1848), *mychias* (1670), *mylothris* (1728), *mysticodes* (1785), *nephelarcha* (1654), *nephelota* (1722), *niphias* (1669), *noserodes* (1741), *notiodes* (1799), *notomolybda* (1795), *obliviosa* (1735), *occidua* (1775), *ocellaris* (1827), *ochronota* (1805), *ochrosticta* (1806), *olympias* (1717), *omotypa* (1861), *orescoa* (1730), *orestera* (1780), *orinoma*

(1720), *oriphaea* (1709), *orthomita* (1784), *orthomochla* (1687), *otiosa* (1789), *oxysema* (1782), *pactolias* (1636), *paracycla* (1836), *parasema* (1807), *partitella* (1713), *phaeocephala* (1818), *phaeochyta* (1770), *phoenopasta* (1639), *pilidiota* (1733), *platyptera* (1723), *poliocneca* (1791), *poliocrossa* (1843), *polybotrya* (1731), *productella* (1754), *profuga* (1721), *protorthra* (1749), *pruinosa* (1738), *psilopta* (1702), *pulverea* (1792), *pycnotypa* (1726), *pyrrhophara* (1857), *rasilis* (1790), *scieropa* (1751), *sciocrossa* (1850), *semifulva* (1853), *siphonistis* (1711), *sobrina* (1834), *sophia* (1712), *spectabilis* (1823), *sphenoleuca* (1718), *spodotis* (1756), *stenosema* (1774), *stenotypa* (1835), *stipulata* (1846), *strigatella* (1635), *symbleta* (1849), *synauges* (1765), *tanaostola* (1755), *tentatella* (1815), *terpnopis* (1824), *tessaradisca* (1683), *tetragona* (1674), *tharsyntis* (1699), *thiogramma* (1656), *trijugella* (1706), *triplectis* (1762), *trivia* (1752), *vera* (1871), *vilis* (1767), *xanthiella* (1838), *xanthocoma* (1772), *xanthodisca* (1680), *xanthoprepes* (1679), *xesta* (1763), *xiphostola* (1652), *xylochroa* (1744), *zanclotoma* (1831), *zophospila* (1773).

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## A CRITICAL REVISION OF R. D. FITZGERALD'S "AUSTRALIAN ORCHIDS".

By the REV. H. M. R. RUPP, B.A.

[Read 29th November, 1944.]

Nothing can ever detract from the high merit of Fitzgerald's great work, in which, during the last quarter of the nineteenth century, he depicted in colour, and with a wealth of intricate detail, approximately two hundred species of Australian Orchidaceae. This number is considerably increased if we include his unpublished plates now in the possession of the Mitchell Library at Sydney; but the present paper is concerned only with those which were actually published and placed on sale or otherwise distributed, by authority of the Government of New South Wales.

Fitzgerald died in 1892; and in the fifty-two years which have passed since then, the study of Australian orchids has made great progress. Considering his limited facilities for reference, his difficulties in the matter of transport of material, and other disadvantages under which he laboured, it was inevitable that Fitzgerald should occasionally have been mistaken in his interpretations of species: indeed, the fact that he made so few mistakes is a great tribute to the accuracy of his botanical insight. Nevertheless, some mistakes were made. Moreover, since his time, the nomenclature of many of the orchids which he depicted has changed—sometimes in obedience to the international rule of priority, sometimes by reason of additional knowledge which has been won concerning the affinities between various species. It seems to the present writer that the time has come when it is most desirable to publish a review of Fitzgerald's work, which shall embody (*a*) necessary alterations in the nomenclature, (*b*) necessary corrections where it is recognized beyond reasonable doubt that Fitzgerald's interpretation of a species was mistaken, and (*c*) any further comments likely to assist in clearing up difficulties encountered by field workers who refer to "Australian Orchids" for the determination of specimens they have collected.

*(a). Alterations in Nomenclature.*

The simplest way to present these is to tabulate them, giving in one column the names adopted by Fitzgerald, together with a reference to the Volume and Part in which each occurs, and in a parallel column giving the corresponding names now accepted as valid. Fitzgerald did not follow any recognized order in the publication of his species; but it is thought best here to adopt the order used by the writer in his "Orchids of New South Wales" (National Herbarium of N.S.W., 1943), which in the main, with a few necessary modifications, follows Pfitzer's arrangement.

FITZGERALD'S NOMENCLATURE.	PRESENT NOMENCLATURE.
<i>Thelymitra megalyptra</i> Fitzg. (I, 5.)	<i>T. aristata</i> var. <i>megalyptra</i> (Fitzg.) Nicholls.
<i>Thelymitra luteociliium</i> Fitzg. (II, 1.)	<i>T. luteociliata</i> Fitzg.
<i>Diuris elongata</i> R.Br. (I, 4.)	<i>D. punctata</i> Sm.
<i>Diuris spathulata</i> Fitzg. (II, 4.)	<i>D. striata</i> Rupp.
<i>Microtis porrifolia</i> Spreng. (II, 1.)	<i>M. unifolia</i> (Forst.) Reichb. f.
<i>Chiloglottis diphylla</i> R.Br. (II, 2.)	<i>C. reflexa</i> (Labill.) Druce.
<i>Chiloglottis Gunnii</i> Lindl. (II, 2.)	<i>C. Gunnii</i> Lindl.
<i>Cyrtostylis</i> R.Br. (I, 4.)	Genus now absorbed into <i>Acianthus</i> .
<i>Cyrtostylis reniformis</i> R.Br. (I, 4.)	<i>Acianthus reniformis</i> (R.Br.) Schltr.
<i>Eriochilus autumnalis</i> R.Br. (II, 2.)	<i>E. cucullatus</i> (Labill.) Reichb. f.
<i>Lyperanthus ellipticus</i> R.Br. (I, 1.)	<i>Rimacola elliptica</i> (R.Br.) Rupp.
<i>Corysanthes</i> R.Br. (I, 1.)	<i>Corybas</i> Salisb.
<i>Corysanthes fimbriata</i> R.Br. (I, 1.)	<i>Corybas fimbriatus</i> (R.Br.) Reichb. f.
<i>Corysanthes pruinosa</i> Cunn. (I, 1.)	<i>Corybas pruinosa</i> (Cunn.) Reichb. f.
<i>Corysanthes bicalcarata</i> R.Br. (I, 2.)	<i>Corybas aconitiflorus</i> Salisb.

## FITZGERALD'S NOMENCLATURE.

- Corysanthes unguiculata* R.Br. (I, 2.)  
*Cryptostylis longifolia* R.Br. (I, 3.)  
*Pterostylis striata* Fitzg. (I, 3.)  
*Pterostylis hispidula* Fitzg. (I, 6.)  
*Galeola Ledgeri* Fitzg. (II, 2.)  
*Epipogon nutans* (Bl.) Reichb. f. (II, 5.)  
*Spiranthes australis* Lindl. (I, 2.)  
*Oberonia palmicola* F. Muell. (II, 3.)  
*Phaius grandifolius* Lour. (II, 5.)
- Dendrobium hispidum* A. Rich. (II, 3.)  
*Dendrobium Taylori* (F. Muell.) Fitzg.  
 (II, 3.)  
*Bulbophyllum* Thou. (I, 5.)  
*Bulbophyllum Shepherdi* F. Muell. (I, 5.)
- Bulbophyllum lichenastrum* F. Muell.  
 (II, 5.)  
*Osyricera* Blume. (II, 5.)  
*Osyricera purpurascens* Deane. (II, 5.)  
*Adelopetalum* Fitzg. (II, 5.)  
*Adelopetalum bracteatum* (F. M. Bail.)  
 Fitzg. (II, 5.)  
*Coelandria* Fitzg. (I, 7.)  
*Coelandria Smilliae* (F. Muell.) Fitzg.  
 (I, 7.)  
*Cleisostoma* Blume. (I, 4.)  
*Cleisostoma erectum* Fitzg. (I, 4.)  
*Cleisostoma tridentatum* Lindl. (I, 5.)  
*Cleisostoma Beckleri* F. Muell. (II, 2.)  
*Cleisostoma Keffordii* F. M. Bail. (II, 2.)  
*Saccolabium Hillii* F. Muell. (I, 2.)  
*Sarcochilus montanus* Fitzg. (I, 5.)  
*Sarcochilus parviflorus* Lindl. (I, 3.)

## PRESENT NOMENCLATURE.

- Corybas unguiculatus* (R.Br.) Reichb. f.  
*C. subulata* (Labill.) Reichb. f.  
*P. alata* (Labill.) Reichb. f.  
*P. nutans* R.Br. var. *hispidula* Fitzg.  
*G. foliata* F. Muell.  
*E. roseum* (D. Don) Lindl.  
*S. sinensis* (Pers.) Ames.  
*O. Titania* Lindl.  
*P. Tankervilleae* (Banks in L'Herit.)  
 Blume.  
*Cadetia hispida* (A. Rich.) Schltr.  
*Cadetia Taylori* (Fitzg.) Schltr.
- Bulbophyllum* Thou.  
*B. crassulifolium* (Cunn. apud Lindl.)  
 Rupp.  
*Dendrobium lichenastrum* (F. Muell.)  
 Nicholls.  
 Absorbed into *Bulbophyllum*.  
*Bulbophyllum MacPhersonii* Rupp.  
 Absorbed into *Bulbophyllum*.  
*Bulbophyllum bracteatum* F. M. Bail.
- Absorbed into *Dendrobium*.  
*Dendrobium Smilliae* F. Muell.
- Genus now considered obsolete.  
*Sarcanthus erectus* (Fitzg.) Rupp.  
*Sarcanthus tridentatus* (Lindl.) Rupp.  
*Sarcanthus Beckleri* (F. Muell.) Rupp.  
*Camarotis Keffordii* (F. M. Bail.) J. J. Sm.  
*Ornithochilus Hillii* (F. Muell.) Benth.  
 A form of *S. falcatus* R. Br.  
*S. australis* Lindl.

The following notes seem necessary in connection with the above:

- (1). *Diuris spathulata* Fitzg.—Fitzgerald's name is invalid, having been appropriated in 1805 by Swartz for the species to which Smith's name *D. aurea* was subsequently restored by the rule of priority.
- (2). *Lyperanthus ellipticus* R.Br.—It had long been felt by orchid workers in New South Wales that this plant occupied an anomalous position in *Lyperanthus*. In the *Victorian Naturalist*, lviii, 1942, p. 188, Rupp made it the type of a new genus, *Rimacola*.
- (3). Genus *Corysanthes* R.Br.—Salisbury's name *Corybas*, though rejected by Bentham (*Fl. Aust.*, vi, p. 350) on ethical grounds, has undoubted priority over Brown's; and since the International Council of Nomenclature has refused to allow *Corysanthes* to be placed on the list of *nomina conservanda*, Salisbury's name must be accepted.
- (4). *Pterostylis striata* Fitzg.—This plant has not been recorded in New South Wales since Fitzgerald's time, but the details shown in his plate indicate its identity with H. G. Reichenbach's *P. alata*, a common species in all the other States except Queensland.
- (5). *Osyricera purpurascens* Deane.—Particulars of the transference of this plant to the genus *Bulbophyllum*, and of the necessary adoption of a new specific name, are given by Rupp in *Vict. Nat.*, li, 1934, p. 81.
- (6). *Adelopetalum bracteatum* Fitzg.—F. M. Bailey's treatment of this plant in *Queensland Flora*, vi, p. 1539, is generally accepted.

- (7). *Coelandria Smilliae* Fitzg.—Fitzgerald thought this so different from any species of *Dendrobium* (in which Mueller had placed it) that he created the new genus *Coelandria* for it. Mueller, however, was right, as the species belongs to a fairly large section of *Dendrobium*, well represented in the tropics north of Australia.
- (8). *Cleisostoma* Blume.—This genus is not now recognized as valid, the numerous species formerly included in it being distributed among *Sarcanthus*, *Saccolabium*, and other allied genera. Two Australian species, *C. Nugentii* F. M. Bail. and *C. Armitii* F. Muell., are retained for the present until material is procured for critical examination. For the distribution of all the other Australian species, see Rupp in *Vict. Nat.*, lvii, 1941, p. 218.
- (9). *Saccolabium Hillii* F. Muell.—This plant has presented considerable difficulties to taxonomic botanists, and a new genus will probably have to be created for it. Schlechter, in fact, stated his intention to make it the type of such a genus, but so far as can be ascertained he did not do so. It is certainly not a true *Saccolabium*; and its removal by Bentham to *Ornithochilus* is not considered very satisfactory.
- (10). *Sarcochilus montanus* Fitzg.—This was subsequently reduced by Fitzgerald himself to a variety of *S. falcatus* R.Br. But intermediate forms are so numerous in some areas, exhibiting combinations of the characters of both type form and variety, that it seems hardly worth while retaining even varietal rank for *S. montanus*.

(b). *Erroneous Interpretations of Species.*

- (1). *Thelymitra canaliculata* R.Br. (II, 3).—It is often very difficult to determine accurately certain closely-allied species of *Thelymitra*, since the distinctions may be almost wholly confined to the smallest floral segment; the column. W. H. Nicholls, in a careful analysis of several of such species (*Vict. Nat.*, xlvii, 1929, pp. 28–33), concludes that the plant figured by Fitzgerald as *T. canaliculata* is a form of the rather variable species *T. media* R.Br. With this conclusion I agree. Brown described *T. canaliculata* from Western Australia; and although it is closely allied to both *T. media* and *T. ixiooides* Sw., I do not now think it occurs in any of the eastern States. Fitzgerald's plate was prepared from specimens collected at Hunter's Hill, near Sydney. If it be compared with his exposition of *T. media* (I, 4), it will be seen that, although the two forms are different, they are not more distinct from one another than are varying forms of *T. ixiooides* or *T. aristata*. One column is rather squat and compact, the other is elongated. But Nicholls shows that the column of the Western Australian flower differs rather strikingly from either. Fitzgerald believed he had found plants identical with his Hunter's Hill form near Albany, W. Aust. But unless one had both forms together, it would not be difficult, where the distinctions are on so small a scale, to make a mistake when examining flowers from localities two thousand miles apart. At all events, the column depicted by Fitzgerald as that of *T. canaliculata* is not reconcilable with that of the western species.
- (2). *Microtis parviflora* R.Br. (II, 1).—The species depicted by Fitzgerald over this name is really *M. oblonga* Rogers. (*Trans. Roy. Soc. S. Aust.*, xlvii, 1923, p. 339.) The details do not agree with those of *M. parviflora*, which has an entire labellum and no anterior callus. The crenulated labellum margins, large anterior callus, and tightly-revolute lateral sepals, of Fitzgerald's figures, are all characteristic of *M. oblonga*.
- (3). *Prasophyllum australe* R.Br. (II, 1).—Unquestionably there is a mistake here. Fitzgerald's plant is quite unlike *P. australe*, which is well illustrated (over the synonym *P. lutescens*) in Hooker's *Flora Tasmaniae*, ii, t. 110 B. The leaf of Fitzgerald's plant gives a clue to its identity; for only one species in this section of *Prasophyllum* has a bract-like leaf—namely, *P. flavum* R.Br. Nicholls reports that this aberrant form of *P. flavum* occurs in north-eastern Victoria; and Fitzgerald's specimens came from the south-east of New South Wales. Nicholls writes that in spite of the "rotund" appearance of the flowers, their morphology is that of *P. flavum*, which incidentally is not always as yellow as its name implies.

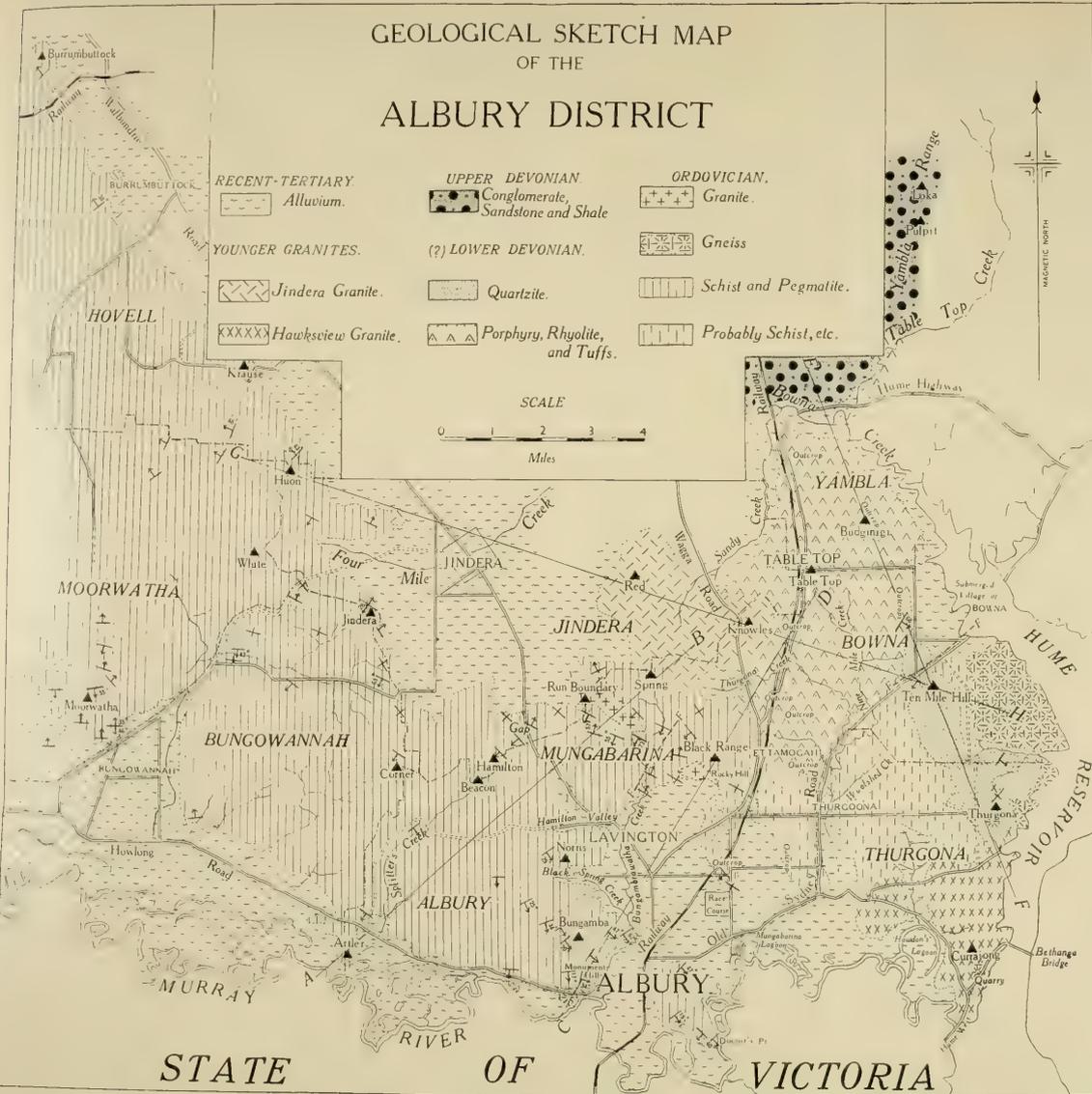
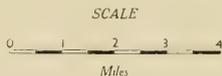
- (4). *Prasophyllum alpinum* R.Br. (II, 1).—The plant figured over this name may confidently be referred to *P. gracile* Rogers (*Trans. Roy. Soc. S. Aust.*, xxxiii, 1909, p. 213). It is not *P. alpinum*, the lateral sepals of which are consistently connate for at least half their length. For further particulars on this subject see Nicholls in *Proc. Roy. Soc. Vict.*, xlvii, 1933, (N.S.), pp. 28–35.
- (5). *Prasophyllum nigricans* R.Br. (I, 5).—Fitzgerald here seems to have figured a form of *P. rufum* R.Br., though it is hardly typical, and the common form is much darker in colour. But see note on *P. rufum* below.
- (6). *Prasophyllum rufum* R.Br. (II, 4).—Fitzgerald's determination of this species cannot be accepted. Nicholls has received drawings of the type from the British Museum, which prove that the species accepted for many years in New South Wales as *P. nigricans* is really *P. rufum*. Distinctions between it and *P. nigricans* of the southern States have been observed for some years, but they were allowed to pass as varietal. Both forms are very different from Fitzgerald's *P. rufum*, which is at present without a valid name. It has not been recorded for many years, and there is only one somewhat doubtful specimen in the National Herbarium at Sydney.
- (7). *Prasophyllum intricatum* Stuart (II, 4).—Stuart's name is invalid. Nicholls (*Vict. Nat.*, xlviii, 1931, p. 105) has shown that his plant is identical with *P. Archeri* Hook. f. Fitzgerald's plant, notwithstanding some morphological resemblance to *P. Archeri*, is now regarded as representing *P. Beagleholei* Nicholls. See "Orch. N.S.W.", 1943, p. 35. An excellent figure of *P. Archeri* is given in Hooker f., *Flora Tasmaniae*, ii, t. 113 B.
- (8). *Drakaea elastica* Lindl. (II, 1).—Determination incorrect. The species figured over this name will be found described by Schlechter in *Fedde Repert.*, xvii, 1921, p. 81, as *D. Fitzgeraldii* Schltr. The author gives full particulars of the specific distinctions.
- (9). *Calochilus campestris* R.Br. (I, 4).—Determination incorrect. A good illustration of *C. campestris* will be found in *Bot. Mag.*, 1832, t. 3187. Fitzgerald's plant appears to be the comparatively rare pale-coloured form of *C. Robertsonii* Benth.
- (10). *Caladenia clavigera* Cunn. (I, 2).—Fitzgerald himself apparently had some doubt about this determination, for he remarks on the discrepancy between his plate and that given by Hooker f. in *Flora Tasmaniae*, ii, t. 222. The latter correctly depicts Cunningham's species. Rogers in *Trans. Roy. Soc. S. Aust.*, xlv, 1920, p. 330, unwittingly increased the confusion between these forms by describing a new species, *C. cordiformis*, from Victorian specimens of *C. clavigera* which all happened to possess non-clavate sepals. Cunningham's name is not particularly appropriate, as the sepals are not always clubbed, and even when they are, the clubs are less conspicuous than in several other species. But *C. clavigera* Cunn. and *C. cordiformis* Rogers are undoubtedly conspecific, and the latter name is invalid. The plant figured by Fitzgerald has been named by Rupp *C. Fitzgeraldii*. (*Vict. Nat.*, lviii, 1942, p. 199; and *Aust. Orch. Rev.*, vii, 1942, p. 64.)
- (11). *Pterostylis Mitchellii* Lindl. (I, 6).—This determination cannot be accepted; Fitzgerald's plant represents a form of the variable species *P. pusilla* Rogers. Neither the galea nor the lower sepals are those of *P. Mitchellii*, and the stigma is much too conspicuous.
- (12). *Bulbophyllum lichenastrum* F. Muell. (II, 5).—The plant figured here is irreconcilable with Mueller's specimens in the Melbourne and Brisbane Herbaria. In *The North Queensland Naturalist* for Sept. and Dec., 1938, Nicholls transferred Mueller's species to *Dendrobium*, and described Fitzgerald's plant (of which he had obtained specimens from North Queensland) as a new species under the name *D. variabile*. Subsequently (*ibid.*, March, 1942) he described another small northern *Dendrobium* as *D. aurantiaco-purpureum*, and stated that he now believed this to be the plant figured by Fitzgerald as Mueller's *Bulbophyllum lichenastrum*. Not having seen specimens of *D. aurantiaco-purpureum*, I cannot express an opinion on this point; but it is sufficient for the present purpose to say that Fitzgerald's plant is not identical with Mueller's.

(c). *Additional Notes and Comments.*

- (1).—*Diuris pedunculata* R.Br. (I, 7).—The large form illustrated by Fitzgerald alongside the typical form, has been named by Nicholls var. *gigantea*. (*Vict. Nat.*, xlix, 1932, p. 174.)
- (2). *Prasophyllum flavum* R.Br. (I, 3).—Though correctly determined, this is hardly the typical form, which is a more robust plant with dull yellowish-green flowers. Occasionally they are not yellow at all.
- (3). *Chiloglottis Gunnii* Lindl. (II, 2).—Apparently the specimens figured by Fitzgerald were received from some distant locality, and suffered in transit for the flowers are shown with their segments almost closed up. Actually they are very widely expanded, and this is the most attractive of all our species of *Chiloglottis*.
- (4). *Calochilus paludosus* R.Br. (I, 4).—It has been stated that Fitzgerald incorrectly depicts the flower of this species. In a note on p. 52 of "The Orchids of New South Wales", I have shown that this opinion is apparently due to a mistaken conception of certain details in the plate.
- (5). *Caladenia Patersonii* R.Br. (I, 3).—It is regrettable that finer specimens of this were not available to Fitzgerald for his plate, which certainly does not do justice to one of the most striking and attractive of all Australian orchid flowers. It displays a wide range of colours, and the sepals occasionally reach a length of 14 cm.
- (6). *Caladenia filamentosa* R.Br. (I, 7).—This fairly represents the typical form, though the perianth-segments are longer than usual. But the species is extremely variable, particularly in Western Australia. Tate's *C. tentaculata*, which was reduced by Rogers to a variety of *C. filamentosa*, is yellowish in colour, with remarkably long, thread-like sepals and petals.
- (7). *Caladenia carnea* R.Br.—Another very variable species, of which only the commonest form is depicted by Fitzgerald. Var. *gigantea* Rogers often has flowers nearly three times as large, while var. *pygmaea* Rogers (probably identical with *C. minor* Hook. f. of New Zealand) is very diminutive.
- (8). *Pterostylis Baptistii* Fitzg. (I, 1).—The unusual character of the foliation in this plate (ascending the stem) suggests that the plant was growing in long grass or undergrowth. Normally, the leaves of this fine Greenhood are in a fairly compact basal rosette. The colouring of the flower is much darker than is found in most localities; but I have seen specimens from Brunswick Heads in northern New South Wales which matched Fitzgerald's precisely.
- (9). *Pterostylis truncata* Fitzg. (I, 4).—As a general rule this is a very dwarf species, the stem sometimes being no longer than the flower.
- (10). *Pterostylis reflexa* R.Br. (I, 5).—Fitzgerald includes in this plate the larger form described by Robert Brown as *P. revoluta*. In these PROCEEDINGS, IV, 1930, p. 414, I have given reasons for maintaining specific distinction between the two.
- (11). *Pterostylis parviflora* R.Br. (I, 7).—Fitzgerald chose a robust form to illustrate this variable species: it is often smaller and more attenuated. He considered Lindley's *P. aphylla* conspecific with *P. parviflora*, and I can find no good reason for separating them.
- (12). *Pterostylis barbata* Lindl. (I, 7).—In at least some of the copies of "Australian Orchids" which I have seen, the colouring of this species is faulty. The curious filiform labellum is densely beset with *bright yellow* hairs. In the plates referred to, they are greenish-brown.
- (13). *Dipodium* (I, 7).—The plant shown here by Fitzgerald with yellowish-green flowers was originally described by F. M. Bailey in these PROCEEDINGS, VI, 1881, p. 140, as a distinct species, *D. Hamiltonianum*. Subsequently he reduced it to a variety of *D. punctatum*; but Cheel (*ibid.*, xlviii, 1923, p. 681) rightly restored it to specific rank.
- (14). *Sarcochilus falcatus* R.Br. (I, 5).—Although this species is sometimes found in the straggling, erect attitude depicted by Fitzgerald, I cannot but feel that he has done scant justice in this case to one of the most beautiful of our smaller epiphytes. For a very fine photograph which correctly shows the usual habit and appearance, see *Aust. Orch. Rev.*, i (3), 1936, Frontispiece.

# GEOLOGICAL SKETCH MAP OF THE ALBURY DISTRICT

- |  |   |  |
|--|---|--|
| <p><b>RECENT-TERTIARY</b></p> <p>--- Alluvium.</p> <p><b>YOUNGER GRANITES.</b></p> <p>▧ Jindera Granite.</p> <p>XXXXX Hawksview Granite.</p> | <p><b>UPPER DEVONIAN</b></p> <p>●●● Conglomerate,<br/>Sandstone and Shale</p> <p>(?) <b>LOWER DEVONIAN.</b></p> <p>□ Quartzite.</p> <p>▲▲▲ Porphyry, Rhyolite,<br/>and Tuffs.</p> | <p><b>ORDOVICIAN.</b></p> <p>++++ Granite.</p> <p>▨ Gneiss</p> <p>▤ Schist and Pegmatite.</p> <p>▥ Probably Schist, etc.</p> |
|--|---|--|



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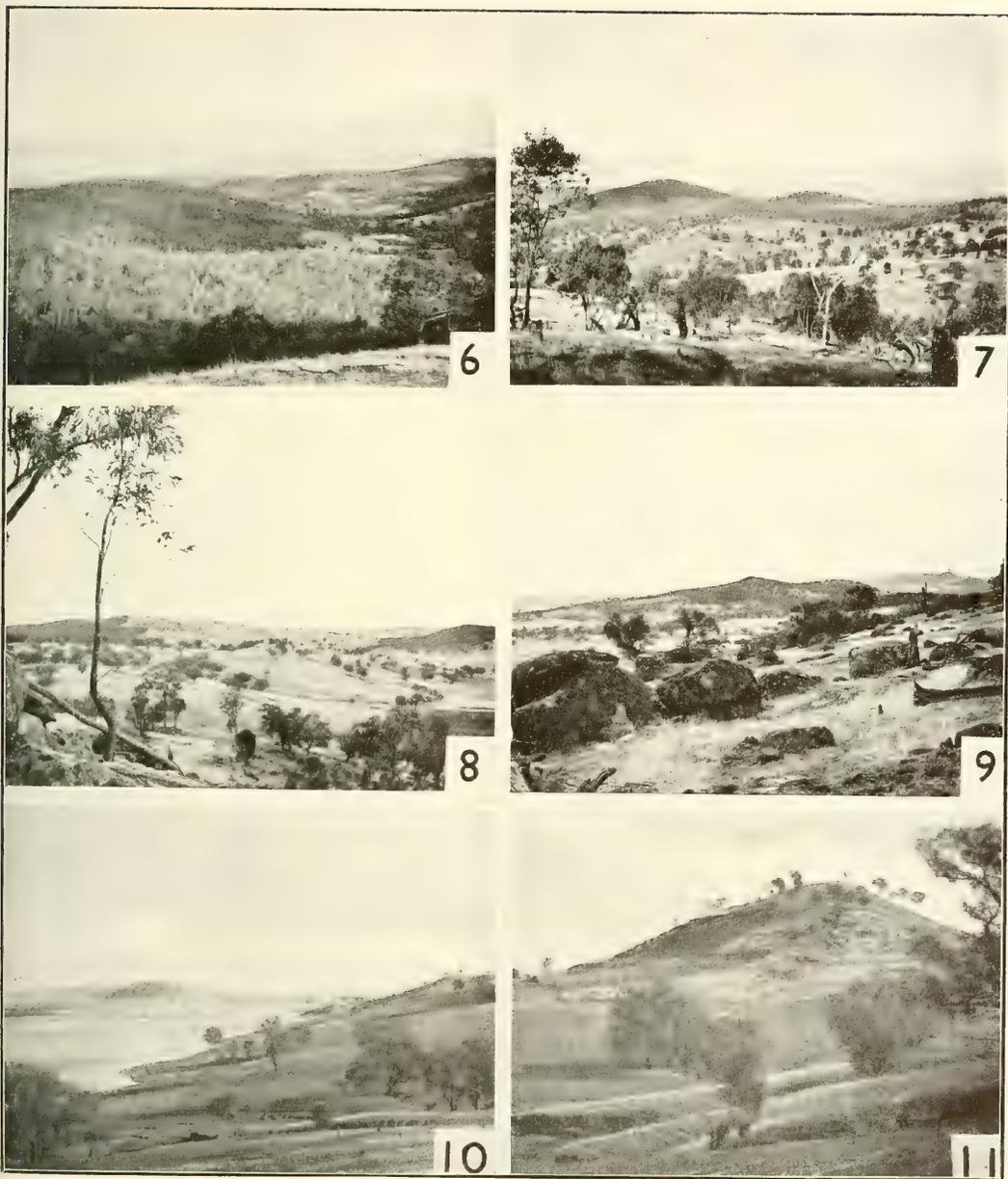
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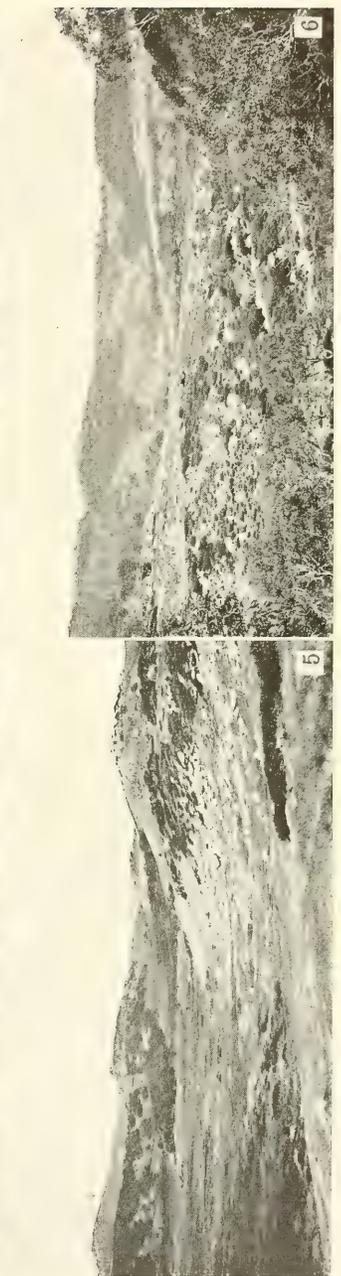
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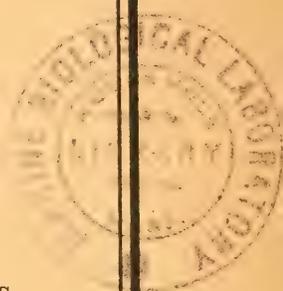
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1879 .. ..	6 0	6 0	8 0	6 6	1902 .. ..	7 0	7 6	7 6 <sup>a</sup>	15 0
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1882 .. ..	7 6	10 0	5 0	10 0	1905 .. ..	6 0 <sup>a</sup>	10 0	12 6	8 0 <sup>a</sup>
1883 .. ..	10 0	5 0	7 0	8 0	1906 .. ..	12 6	12 6	12 6	15 0
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1940	11 9	10 6	8 0
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[Plates ii-v.]

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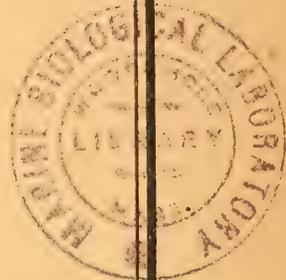
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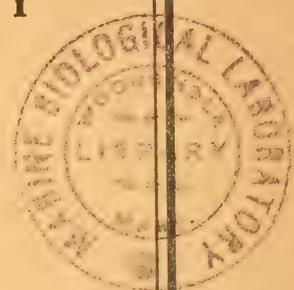
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