

CONTENTS OF PROCEEDINGS, VOLUME 99

Proceedings of the Linnean Society of New South Wales

VOLUME 99

Nos. 437-440

CONTENTS OF PROCEEDINGS, VOLUME 99

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(Issued 12th November 1974)

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The *Proceedings of the Linnean Society of New South Wales* contain original papers relative to "the Science of Natural History in all its branches", and reports of business transacted at the meetings of the Society.

NOTES AND INSTRUCTIONS FOR AUTHORS

Original papers may be submitted for consideration for publication in the Society's Proceedings. Submission of a manuscript must imply that the contents are original and have not been published previously in the same, similar, or abbreviated form, and that no similar paper is being or will be submitted for publication elsewhere until it has been either (a) not accepted for publication by the Society or (b) withdrawn by the author.

Papers submitted should embody the results of a significant piece of work. Interim reports, serialized studies and student theses should not be submitted.

Papers are accepted for publication (or otherwise) by the Council of the Society after taking into consideration advice received from at least one referee. The decision of Council is final.

Once accepted for publication a paper becomes the property of the Society, and copyright is vested in the Society. Reproduction of the author's synopsis in abstracting journals is authorized.

A paper may be withdrawn by the author at any time prior to acceptance.

Papers may be submitted by members or non-members of the Society but a paper submitted by a non-member must be communicated by a member of the Society, and will not ordinarily be considered for acceptance before July in each calendar year.

SUBMISSION OF MANUSCRIPTS

Manuscripts should be forwarded to the Secretary, The Linnean Society of New South Wales, 157 Gloucester Street, Sydney, N.S.W. 2000.

Text and illustrations must be submitted in duplicate. The illustrations may be duplicated by any acceptable clear method and the duplicate set need not necessarily be identical in size with the originals. The author should retain a third copy for checking proofs. If a paper is not accepted for publication, the original copy of the typescript and illustrations will be returned to the author, but the duplicate copy may be retained by the Society.

Owing to the ever growing costs of publication, authors are requested to write their papers clearly and concisely and exercise all reasonable economy in the number and form of illustrations and tables.

Grants towards the cost of publication should be secured wherever possible from the author's own institution or elsewhere; contributions from authors, especially non-member authors, may be requested at Council's discretion, particularly in the case of lengthy papers, or those with numerous illustrations or tables.

Manuscripts must be submitted in final, fully corrected form. Authors may be liable for the cost of proof corrections (if allowed) if the number of alterations and corrections is considerable. Authors are urged to submit their paper to a colleague for constructive criticism prior to final typing and submission for publication.

MANUSCRIPTS

Papers should be typewritten, double spacing throughout, on one side of quarto or foolscap paper, with at least one-inch margins all round. The desired position of all text-figures, maps and tables may be indicated in the margin. All pages should be numbered serially and securely fastened together. Papers should conform to the following general layout as far as practicable or appropriate:

(a) *Title*.—The title should be concise but informative. The name(s) of the author(s) and the name of the institution where the work was carried out should follow the title. The name of a new taxon of plants or animals should not be included in the title. A short title appropriate for the running heading of subsequent pages may be suggested. The title, etc., should be on a *separate page* at the commencement of the typescript.

(b) *Synopsis*.—A concise abstract (without abbreviations), preferably consisting of not more than about 200 words, should be supplied on a *separate sheet* and in *triplicate*. It should be complete in itself and indicate the scope of the work. It will be printed below the title of the paper; it will be available for reprinting by abstracting journals.

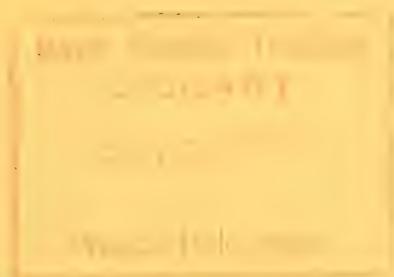
(c) *Table of Contents*.—This should give the complete hierarchy of headings and sub-headings used in the subject-matter of the paper. It should be supplied on a *separate sheet* for guidance of the editor and will not ordinarily be printed.

(d) *Introduction*, followed by the *Subject Matter* of the paper. Papers may be divided into sections described by short headings.

(e) *Discussion, Conclusions or Summary* (if necessary).—This should summarize the conclusions reached rather than be a *précis* of the paper as a whole (cf. *Synopsis*).

Proceedings of the Linnean Society of New South Wales

Issued 11th November, 1974



VOLUME 99
PART I
No. 437

The Linnean Society of New South Wales

Founded 1874. Incorporated 1884

“ For the cultivation and study of the science of Natural History
in all its branches ”

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The Society's Headquarters are in Science House, 157 Gloucester Street, Sydney,
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- (i) The spelling of authors' names is consistent, and the dates, volume numbers and page numbers are correct.
- (ii) All authors quoted in the text are included in the list of references.

References should be cited in the text by the author's name and date, e.g., Bullough (1939) (Bullough, 1939) according to context, and listed alphabetically under References thus :

Bullough, W. S., 1939.—A study of the reproductive cycle of the minnow in relation to the environment. *Proc. zool. Soc. Lond.*, Ser. A, 109 : 79–108.

If more than one reference by the same author(s) published in the same year is cited, use a, b, etc., after the year in both text and list, e.g., Bullough (1939a).

Titles of books must be given in full together with the place of publication, name of publisher and indication of edition if other than the first.

Latin names of plants and animals (genera, species and their subdivisions) should be underlined to indicate italics. An initial capital letter must be used for Latin names of orders, families and similar names, but these should not be underlined.

Abbreviations.—Only standard abbreviations should be used; authors should refer to the British Standard 1991: Part 1, 1967. Recommendations for Letter Symbols, Signs and Abbreviations. The abbreviations of names of periodicals should conform to those in the World List of Scientific Periodicals.

Footnotes should be avoided as far as possible.

Codes of Nomenclature.—The Botanical and Zoological Codes of Nomenclature must be strictly followed. If a new taxon is described, the institution in which the type material is deposited must be indicated.

Language.—Papers in languages other than English are unlikely to be accepted for publication. Foreign authors are urged to seek assistance, if necessary, in rendering the paper in fluent English prior to submission.

Measurements must be expressed in the metric system as far as practicable, and exclusively in scientific description.

ILLUSTRATIONS AND TABLES

The maximum dimensions available for either text-figures or plates are 20 × 12.5 cm.

Black and white drawings and diagrams for text-figures should be in Indian ink on smooth white card such as Bristol board, the lines cleanly drawn, and due attention paid to the consequences of reduction. Graphs should similarly be in Indian ink on white card, or on faint blue-lined co-ordinate paper. Maps should be in Indian ink on white card or tracing linen; in the latter the linen should not be folded. Maps should be of a size and scale that can be conveniently reduced to the size of a single page.

It is desirable that all black and white illustrations should be drawn $1\frac{1}{2}$ -2 times the size that they will appear in print.

Photographs for half-tone plates should be the size required for final reproduction or slightly larger, printed on glossy paper, of good contrast and best quality. A number of small photographs can be arranged to form one plate.

Illustrations for colour reproduction cannot be accepted unless the author meets the difference in cost between black and white and colour reproduction.

Illustrations of all kinds should bear the author's name and the number of each, lightly pencilled on the back, and their required orientation clearly indicated.

Legends for illustrations should be typed on separate sheets at the end of the manuscript. Great care should be taken in stating magnifications of illustrations, making it clear whether numbers quoted refer to before or after reduction.

Tables.—Tables should be numbered consecutively and referred to specifically in the text by number. Each table, together with a heading descriptive of its contents, should be submitted on a separate sheet. Elaborate tables should be avoided.

GENERAL

Proofs.—A set of galley proofs will be forwarded to the author who should correct and return them promptly to the Secretary.

Reprints.—Twenty-five reprints are supplied free to authors who are members of the Society. Additional reprints may be ordered at the authors' expense, if desired. No free reprints are supplied to non-members, who may order the number required at their own expense. Orders for reprints should be placed with the Secretary immediately after the paper has been accepted for publication. Orders received after the paper has been printed may not be accepted.

Joint Authorship.—In the case of papers by more than one author, one of them must accept responsibility for all correspondence with the Society regarding the paper.

ANNUAL GENERAL MEETING

27th MARCH 1974

The Ninety-ninth Annual General Meeting was held in the Society's Rooms, Science House, 157 Gloucester Street, Sydney, on Wednesday, 27th March 1974 at 7.30 p.m.

Dr. P. J. Stanbury occupied the chair. The minutes of the Ninety-eighth Annual General Meeting (28th March 1973) were read and confirmed.

REPORT ON THE AFFAIRS OF THE SOCIETY FOR THE YEAR 1973

Publications

The Society's *Proceedings* were published on the following dates during the year :

1972 Vol. 97, Part 4	30th April 1973
1973 Vol. 98, Part 1	25th June 1973
1973 Vol. 98, Part 2	10th October 1973
1973 Vol. 98, Part 3	16th January 1974

The cost of publishing the *Proceedings* was as follows :

	\$		\$
Blockmaking (Illustrations)	836.12	Subscriptions	3,935.21
Printing	2,870.10	Miscellaneous Sales	682.83
Postage	103.70		
Cost of Reprints :	Printing : \$960.76 ;	Sales : \$762.03	

As reported last year, in order to comply with Post Office regulations, a proportion of every member's subscription is set aside specifically as a subscription to the *Proceedings* ; this amount remains at \$5.00 per annum.

It was regretfully decided during the year to increase the annual charge for the journal from \$11.00 to \$15.00 for subscribers other than members, due to the considerable increase in costs since the last variation in 1965/66.

Membership

During the year 13 new members were admitted to the Society and four resigned. The numerical strength of the Society at the 1st March 1974 was Ordinary Members, 268 ; Life Members, 29 ; Corresponding Members, 4 ; total, 301.

Monthly Meetings

Addresses were given at the meetings in March, April, June, July and September. A Field Day was held in October and the Notes and Exhibits evening took place as usual in November. Details of these may be found in the Abstract of Proceedings, Vol. 98, Part 4, (1973).

Library

Cataloguing of the serials held by the Society has now been completed. New and amended entries for the serials collection were sent to C.S.I.R.O. in March 1973 for inclusion in Scientific Serials in Australian Libraries. Many of these entries have already appeared in amended pages of SSAL.

The number of requests for photocopies of reference material not only from libraries in Australia but from as far afield as Malaysia and New Zealand, has continued to increase.

Publications of the British Museum held by the Society have been catalogued, and a subject list sent to all Australian university libraries, museums, herbariums and relevant divisions of C.S.I.R.O.

A letter was sent to Sydney University requesting information on the progress made regarding the arrangements and cataloguing of monographs sent to that University to be held as a Special Collection. The reply received indicated that the work was in progress but no catalogue cards have yet been received. Cards were received for a number of serials which had been transferred because they were not related to the Society's subject fields.

Work has begun on the Cumulative Index to the Linnean Society's *Proceedings*: 1926 to date. It is hoped to publish this on the completion of volume 100.

Acknowledgement was received from the Mitchell Library for maps, portraits, notes, etc. which relate to the Society's affairs and are now held by that library.

Library Fund

The Royal Society of New South Wales recently established a Library Fund to which donations are tax-deductible to the donors. The conditions imposed by the Commissioner of Taxation permit the fund to be used for such purposes as removal, rehousing, equipping and maintaining the library.

This Society has been quick to follow this example and has now been granted the same concession on the same terms, and a Library Fund has now been established.

The Councils of the two Societies have agreed to devote any moneys accumulated in their respective Library Funds to the costs of alteration of such parts of the new Science House as are required for library purposes and to equipping the libraries in their new home.

It is intended to inaugurate a fund-raising scheme during the year, details of which will be announced later.

Linnean Macleay Fellowship

Dr. Ross A. McLean was appointed Linnean Macleay Fellow as from 1st January 1974 in the Department of Geology and Geophysics, Sydney University. His research topic is a general study of rugose coral faunas of Middle and Upper Silurian age from New South Wales.

Linnean Macleay Lectureship in Microbiology

The appointment continues to be held by Dr. K. Y. Cho. The main research activities are still concerned with the physiology of the extreme halophilic bacteria and the regulation of membrane synthesis in *Azotobacter vinelandii*.

Carotenoids of the extreme halophilic bacterium *Sarcine morrhuae* have been characterised by thin layer chromatography, spectrophotometry, and nuclear magnetic resonance. They are similar to those present in *Holobacterium salinarium*, including the presence of the unusual C₅₀ carotenoids.

Some of the possible membrane precursors in *Azotobacter vinelandii* have been partially purified and characterised.

Finance

The Honorary Treasurer presented the Balance Sheets and Income and Expenditure Accounts of the Society's four Funds and made the following comments on them:

In the General Account balance sheet you will note that a year ago the accumulated funds stood at \$123,446.88. From this has been deducted the advance of \$15,500 on compensation for Science House that we had received by then. This sum has subsequently been added into the surplus of \$409,442.51 on resumption of Science House. You will remember that we received a total of \$438,000 as compensation for the Society's share of Science House. From that sum has been written off both our previous investment of \$30,000 in the building and legal costs incurred in connection with the resumption. The net figure of \$409,442.51 includes our share of the small reserves in the hands of Science House Management Committee.

Our expenditure during the year has exceeded income by \$6,043.53. This amount is approximately equal to the rent we now pay for our premises and the Librarian's salary. Our bank account in this Fund shows a deficiency of \$449.33 as at 28th February 1974.

The right hand side shows how the moneys in this Fund are held. Under fixed assets I point out the third item—the investment of one share of \$1 in Science House Pty. Ltd. Then are listed the various interest-bearing investments. The second last, Science House, represents our share in the reserves held by Science House Management.

Under current assets is listed the loan of \$407,500 to Science House Pty. Ltd. for the Science Centre project. While it is hoped that this will ultimately yield a satisfactory return, immediate financial benefit cannot be anticipated. In early March \$7,500 of this loan was repaid to the Society.

In the Income and Expenditure Account, the printing costs of the *Proceedings* seem much lower than last year. This year the bill for the last part was not received before the balance sheet was drawn up, whereas last year the Account included the cost of five parts.

Income was received from subscriptions both for membership and for the *Proceedings*; from reimbursement of salaries and fees from Science House Management; from interest received from our investments; from the surplus transferred from the Fellowships Account; from rents; from the sale of copies of the *Proceedings* and reprints; from our share in the surplus from Science House Management.

The Bacteriology Account shows little change from last year. Our contribution towards the salary of the Linnean Macleay Lecturer in the University of Sydney has been increased to \$2,000.

The Scientific Research Fund has increased through interest and donations to \$5,554.10.

The Fellowships Account has been augmented chiefly by the transfer of \$2,666.68 from its Income and Expenditure Account. Our Fellow resigned early in the financial year and in accordance with Sir William Macleay's Will the remaining salary was capitalised.

Report on Science Centre

At the Annual General Meeting in 1971 members were informed that Science House (owned jointly by the Linnean Society of N.S.W., the Royal Society of N.S.W. and the Institute of Engineers) had received notice of resumption from the Sydney Cove Redevelopment Authority. At that time negotiations were in progress with the Authority and with the Government of New South Wales in hopes of finding means whereby the learned Societies could rehouse themselves on a site within the redeveloped area.

At the Annual General Meeting in 1972 members were advised that the Societies had requested the Government of New South Wales to provide, as it had done in 1928, a new site for these Societies to rehouse themselves. The

Societies had resolved to accept responsibility for the building of a new Science Centre, as they had in the building of Science House some 44 years ago. The Government had encouraged the Planning Committee in its efforts and had indicated that it would give as much support as possible to our scheme. The Planning Committee, with a membership of representatives appointed from both Societies, was meeting regularly and engaging in broad initial planning and in clarification of the position of both Societies in relation to the project. A claim for compensation for Science House had been made (through Science House Management Committee, which represents jointly the three owner bodies). It was the intention of the Linnean and Royal Societies to invest the compensation money (excluding the amount which had been claimed in respect of disturbance costs) in a new Science Centre. Sites in the Rocks area were under consideration, and a firm of property consultants was assisting the Committee in its investigations, together with the solicitors who were the legal advisers in respect of the present Science House.

You were also advised that the Act of Incorporation of the Linnean Society of New South Wales of 1884 was unduly restrictive in relation to powers of investment and since this could hamper operations concerned with a new building action was being taken to secure a revised Act of Incorporation. It was also foreshadowed that in order to act jointly in relation to the Science Centre action would be taken to form a company. Negotiations with State and Federal governments were continuing.

Having briefly reviewed matters that have been reported to you earlier, I would now like to record events up to the present.

By the middle of 1972 it was becoming clear that re-establishment within the Rocks redevelopment area, as earlier envisaged, would not be a practicable proposition. The Act under which the Sydney Cove Redevelopment Authority operates stipulates that all land within the area shall be leasehold not freehold. The normal term of lease would be 50 years. Though in our case it might have been possible to have this extended to not more than 99 years, upon termination of the lease all land and improvements on it (i.e. buildings) would revert to the Government without compensation; this meant that any money expended by the Societies on a building would then be lost to them forever. Not being organisations trading for substantial profits, the Societies could not entertain this proposition. We suggested that a lease be granted to us at a peppercorn rental but this concession was not within the powers of the Authority to grant. At this time and again at a later stage we asked for a government-guaranteed loan, but our Societies do not fall within existing legislation enabling that to be done and the Government of New South Wales has not agreed to altering the legislation to enable it to be done. It was becoming clear that, although we cannot negate benefits that may yet come, the attitude of the Government was that we had received a generous amount of compensation and should stand on our own feet.

The Planning Committee therefore determined to seek a freehold property that would be suitable for the erection of a Science Centre. It accepted the principle that, to be appropriate for the Societies' needs, any site selected must be reasonably central and accessible to public transport.

Between about June 1972 and December 1973, the Planning Committee (or when the Company was registered its Board of Directors) examined a number of sites and feasibility studies of them to enable a choice to be made appropriate to our needs and financial circumstances. As you can appreciate it is by no means easy to acquire blocks of land in the city or its immediate environs and valuations are very high. It soon became clear that sites within the central city zone (between George and Elizabeth Streets) were quite beyond our means, so thoughts were directed to areas outside but adjacent to the central area.

It would be unavailing to detail either the propositions we have examined which for one reason or another came to nothing or the hopes and frustrations the Committee experienced. Suffice it to say that our property consultants made offers on our behalf for two separate sites which were regarded as financially suitable, and up until about August 1973 the Company had strong hopes of obtaining one of these.

You will recall that about September 1973 a marked change in economic circumstances took place in the community with a dramatic increase in the already high rates of interest payable upon borrowings. Your Company's proposals were inevitably severely affected by this change since it would be obliged to borrow heavily for erection of a building. Our property consultants then expressed the view that within the context in which we had been thinking we simply did not have a proposition at all. It seemed that matters had come to a standstill.

For the purposes of making a feasibility study of one of the sites I have just mentioned a firm of architects, Jackson, Teece, Chesterman and Willis, had been commissioned to draw up sketch plans of a building so that it could be appropriately costed. Learning of our dilemma, this firm, late in October 1973, informed the Societies of an existing building which was for sale and which they felt could be adopted structurally to the Societies' needs.

The Directors and their architects and financial advisers turned their attention to this new proposition of purchasing an existing building on an attractively central and accessible site, and of progressively renovating it as a Science Centre.

The Directors resolved by majority vote on 14th November 1973 to proceed with this proposition. Although it was manifest that strict economy and good housekeeping would be required for its success, an equally good opportunity was unlikely to occur again in the foreseeable future. Our Secretary had meanwhile secured an undertaking for a bank loan on terms that under present conditions must be regarded as unusually favourable. The Directors' resolution to proceed with the acquisition and development of the site was confirmed on 12th December 1973 after further study of all the implications.

I cannot conclude my report on the purchase of the site of our new home without recording our indebtedness to the vendors for their co-operative approach to all the problems and technicalities that beset the two parties during negotiations leading to the signing of the contract.

I must also pay tribute to the tremendous effort of the Company's Secretary, who is also this Society's Secretary, in furthering the project and by her initiative and energy finding means of surmounting what at times appeared insuperable difficulties.

Science House Pty. Ltd.

At the Annual General Meeting 1973 it was reported that the total compensation offered and accepted for Science House amounted to \$1.314 million, and that the Linnean Society's share of this was \$438,000. A lease agreement had been negotiated with the new owner, the Sydney Cove Redevelopment Authority, enabling the previous three owner bodies to continue to occupy and manage Science House for the time being, in return for a reasonable annual rental. Since the Institution of Engineers desired to be relieved of the management services associated with Science House, which it had undertaken for many years past, the Linnean Society with the concurrence of its Secretary, Mrs. Inall, had agreed to accept this responsibility for a fee met jointly by the three bodies.

A Board of Directors for a proposed company had been nominated by the Royal and Linnean Societies in anticipation of its early registration.

Our solicitors however advised against early registration of the company under the New South Wales Companies Act (1961) until we had both reached

a more advanced stage of planning, necessitating the use of the company for joint action and received written assurance that, just as the Linnean and Royal Societies were respectively exempt from income tax, so would the company jointly owned by the two Societies be exempt from income tax.

Satisfactory advice to this effect having been received from the Taxation Commissioner, it was resolved at the meeting of the Planning Committee on 15th March 1973 that the company be registered as soon as possible, each Society owning one share of \$1.00.

For purely historical interest it may be mentioned that an existing but inactive registered company with the improbable name of Hodilia Pty. Ltd. was taken over by the Planning Committee under the guidance of our solicitors. Its previous directors resigned and the following persons were appointed by the Councils of the two Societies as its Directors on 12th April 1973 :

Royal Society : Mr. Edric Keith Chaffer
 Mr. John William Humphries
 Mr. Maurice James Puttock
 Professor William Eric Smith

Linnean Society : Professor Derek John Anderson
 Dr. Harold George Cogger
 Professor Neville George Stephenson
 Dr. Joyce Winifred Vickery

Mrs. R. J. Inall was appointed Company Secretary. The registered office of the Company is 3rd Floor, 157 Gloucester Street, Sydney.

At the first meeting of the new Board of Directors of Hodilia Pty. Ltd. on 26th April 1973, the memorandum changing the name of the Company to Science House Pty. Ltd. was read. The Directors proceeded with business under this name which we trust will continue for the indefinite future.

Dr. H. G. Cogger and Professor D. J. Anderson resigned from the Board of Directors in November 1973, and the Linnean Society appointed Mr. D. W. Edwards and Dr. P. J. Stanbury to the Board in their places.

Each Society has loaned to the Company the sum of \$400,000 totalling \$800,000 free of interest for the time being, for the purposes of the Science Centre project. This money has been invested on short-term loan and has meanwhile earned interest that will enable the Company to meet its administrative expenses and pay \$810,000 towards the acquisition of the site and building.

Financial Advisers

You were informed at the last Annual General Meeting that the Science Centre Planning Committee appointed three honorary financial advisers, Mr. J. Studdy, Mr. J. Bragg and Mr. H. McCredie. The Company has valued their advice during the last anxious year, and we are very grateful for the service they have so willingly rendered.

Annual Elections

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

President : Professor T. G. Vallance.

Members of Council : Dr. H. G. Cogger, Mr. D. W. Edwards, Miss E. C. Pope,
 Dr. L. A. Moffat, Mr. G. P. Whitley.

Auditors : W. Sinclair & Co.

PRESIDENTIAL ADDRESS

THE ROLE OF SCIENTIFIC SOCIETIES—SOME SUGGESTIONS FOR THE FUTURE

by P. J. STANBURY

For the past year I have been President of our Society which we claim is devoted to science. We are a wealthy Society. You know the plans for constructing Science Centre at a cost of two million dollars. We are a Society whose membership has included most of the important natural scientists of this State. World-renowned visitors have lectured in this room. Yet what benefit has the wealth and talent of the Society brought to most of its members or to the general public of New South Wales?

Attendances at recent meetings have been very poor. Less than 10 per cent of members have attended a monthly meeting in the last year. Can any society continue to function under these conditions?

The Royal Society of New South Wales had trouble with attendance over a century ago. At that time it was called the Philosophical Society of New South Wales. It solved its problems by attaining royal patronage and changing its name.

At that Society's recent annual dinner Sir Roden Cutler, one of its Patrons, said:

"The rapidly increasing fields of scientific study and the proliferation of scientific knowledge in recent years almost makes it an impossible task for [a] society to keep the public informed. Scientific investigations and discoveries in the last 25 to 30 years have both excited public imagination and at the same time occasionally frightened the public. [A] society's task is to bring a balance into people's assessment of the advantages and limitations of scientific progress. You need to encourage research and investigation, and occasionally express a word of warning".

Since I have been Curator of the Macleay Museum at the University of Sydney it has recovered from a period of sad neglect and is now growing and expanding. The Macleay Museum grew, as you probably know, from the collections of Alexander, William S. and Sir William Macleay. Sir William donated the total collection to the University in 1886. I have always felt his presence there strongly. Today the Museum is being used and many thousands of people each year have reason to feel grateful for Sir William's generosity. In my work for the survival and restoration of this Museum I have gained some experience in determining what will raise a body from the dead and give it a new lease on life.

This year the Council of our Society has considered ways and means of enlivening the meetings. The Future Role of the Society Sub-committee has been formed. Soon you will receive a circular asking your views on the relative importance of a number of activities, including the publishing of the *Proceedings*, which is the one thing we believe we do well. We shall be trying out a new style of meeting this year. Your response to these things will determine what we do next year.

However, I am now concerned with the future of scientific societies in the long term. How can Sir Roden Cutler's remarks be brought to fruition? I can think of two possible ways.

First, I believe that a society like ours could employ a public information officer who would have the job of advertising the society's activities and of informing both its members and the public at large of its doings.

At one time no one paid much attention to scientists unless it was to remark on their supposed eccentricity. However, by the 1930's scientists were becoming regarded as people who could solve problems. Today scientists are accepted as a normal part of society. The media on the whole report on the work of a scientist or scientists with no more or less enthusiasm than on the doings of any other individual or group in society. Most often the media pay no attention to scientists at all unless scientists deliberately draw attention to themselves. As a rule scientists are very hesitant to do this. The ones who do are usually most adept at raising not only the interest of the public but also large sums of money to be used on research.

With these considerations in mind I shall list the possible duties of a public information officer for a scientific society. He should inform, advertise and stimulate interest both within and outside the society. He would produce newsletters for the members, which would contain, among other things, discussion of the issues being considered by the society's executive body. He would present accounts of the members' current research in the newsletters. He would be responsible for feeding selected information of significance and interest to the public media for dissemination to a wide audience. He should have the experience and qualifications to maintain a strong working relationship with those who control the media. An information officer must be free to speak independently and should be responsible to the executive body of the society only through the president. He must gain and maintain the confidence of the members of the society. Scientists often need to be persuaded of the significance of their work, and an information officer could assist in this area. The officer should present the president or the executive body as the public image of the whole society, thus providing some tangible link between the public and the members.

An information officer should address as many groups as possible both within and outside the society. He must be an active man, providing liaison among the executive body, the member scientists, the media and individuals and groups of the general public. His job is to dispell inertia, apathy and ignorance. He can do this by employing his knowledge and experience, by using tact, by radiating and rousing enthusiasm and by using for the society's profit the same methods of persuasion employed by advertisers and salesmen in the commercial world. An information officer must use modern methods.

This brings me to my second suggestion for enlarging and enlivening a society's activities. This is the use of radio.

It is hardly likely that a society like ours could acquire substantial regular broadcasting time on the ABC or on commercial radio. However, we could investigate the alternative types of radio which include adult and extension programmes, University of the Air private stations, radio stations with low output which are virtually closed circuit radio, and Frequency Modulation (FM) radio.

If FM radio is introduced into Australia, it is probable that many community group radio stations will spring up. I suggest that the Linnean Society could make good use of an FM group station. We could, for example, broadcast weekly in the evening, giving news of special interest to scientists; details of available grants; job opportunities; information on new equipment; consumer reports on scientific equipment; news and information for members; talks, lectures and courses; advice to conservation groups and other environmental bodies; reports on the best places to see flora, fauna and geological phenomena, and many other activities.

If we found difficulty in compiling enough material for our own weekly programme, we could join together with other societies for the purpose of the broadcast. This idea is in line with the concept of the Science Centre that the Royal and Linnean Societies are striving to establish. The Centre is envisaged as a building in which many scientific societies may have offices and facilities for their mutual benefit.

The initial cost of a radio station is \$75,000. We should consider how our Society can best look to the future and how it can best serve the general public. No longer can scientific societies and scientists keep ostrich-like attitudes. The future of this country depends on the co-operation of all members of its population. How can you, as a scientist, best serve the community ?

LINNEAN SOCIETY OF NEW SOUTH WALES

GENERAL ACCOUNT

Income and Expenditure Account for the Year Ended 28th February 1974

EXPENDITURE		INCOME	
1973	1973		
\$	\$		\$
250	325.00	Subscriptions—	
442	522.85	Members'	512.00
206	176.03	Proceedings	3,939.76
734	266.25		4,451.76
1,046	836.12	Science House Management Reimbursement—	
85	75.98	Salaries	1,384.00
138	240.55	Management Fees	750.00
250	250.00		
98	76.59	Interest Received	
641	719.66	Fellowships Account—	
5,234	2,870.10	Surplus Income for the Year ended 28th	
526	512.97	February 1974	4,134.49
95	145.56	Rents Received	59.00
195	190.66	Reprints Sales	762.03
924	960.76	Sales	713.33
14,316	13,857.31	Science House—	
3,556	3,778.25	Share of Surplus	1,592.26
485	160.49		
		Total Income	19,921.80
		Deficiency for Year Transferred to Accumulated	
		Funds	6,043.53
\$29,221	\$25,965.13		\$25,965.13

AUDITORS' REPORT

We have audited the books and records of the Linnean Society of New South Wales for the year ended 28th February 1974, and are of the opinion that the above Balance Sheet and accompanying Income and Expenditure Account correctly set forth the position of the financial affairs as at 28th February 1974, according to the explanation given to us and as disclosed by the books of the Society.

W. SINGLAIR & Co.
Chartered Accountants, Auditors.

Registered under the Public Accountants Registration Act 1945,
as amended.

DATED at Sydney this fifteenth day of March 1974.

15th March 1974

JOYCE W. VICKERY,
Hon. Treasurer.

LINNEAN SOCIETY OF NEW SOUTH WALES

BACTERIOLOGY ACCOUNT

Balance Sheet as at 28th February 1974

1973 \$		1973 \$	
	Accumulated Funds—		Investments—
	Balance, 1st March 1973:	26,900	Commonwealth Loans—At Cost
	Amount Bequeathed by Sir William	—	Debentures
	Macleay	24,000.00	British Petroleum Company of Australia Ltd.
	Transfers from Income Account, etc.	13,591.75	Metropolitan Water, Sewerage and Drainage
	.. .. .	37,591.75	Board—At Cost
	Add Surplus for Year	219.82	Loan on Mortgage
	Balance, 28th February 1974	37,811.57	Current Assets—
37,592			Cash at Bank
			911.57
			<u>36,900.00</u>
			<u>87,811.57</u>

Income and Expenditure Account for the Year Ended 28th February 1974

1973 \$		1973 \$	
	University of Sydney:	2,214	Interest Received
1,850	Salary of Lecturer	2,000.00	
364	Surplus for the Year	219.82	
			<u>2,219.82</u>
			<u>\$2,219.82</u>

AUDITORS' REPORT

We have audited the books and records of the Linnean Society of New South Wales for the year ended 28th February 1974, and are of the opinion that the above Balance Sheet and accompanying Income and Expenditure Account correctly set forth the position of the financial affairs of the Bacteriology Account as at 28th February 1974, according to the explanations given to us and as disclosed by the books of the Society.

W. SINOLAIR & CO.,

Chartered Accountants, Auditors.

Registered under the Public Accountants Registration Act 1945,

as amended.

DATED at Sydney this fifteenth day of March 1974.

15th March 1974.

JOYCE W. VICKERY,
Hon. Treasurer.

LINNEAN SOCIETY OF NEW SOUTH WALES
LINNEAN MACLEAY FELLOWSHIPS ACCOUNT
Balance Sheet as at 28th February 1974

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Income and Expenditure Account for the Year Ended 28th February 1974

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AUDITORS' REPORT

We have audited the books and records of the Linnean Society of New South Wales for the year ended 28th February 1974, and are of the opinion that the above Balance Sheet and accompanying Income and Expenditure Account correctly set forth the position of the financial affairs of the Linnean Macleay Fellowships Account as at 28th February 1974, according to the explanations given to us and as disclosed by the books of the Society.

W. SINGLAIR & Co.,
Chartered Accountants, Auditors,
Registered Under the Public Accountants Registration Act 1945,
as amended.

JOYCE W. VICKERY,
Hon. Treasurer.

15th March 1974.

DATED at Sydney this fifteenth day of March 1974.

ROBERT DOMROW*

[Accepted for publication 21st November, 1973]

Synopsis

A miscellaneous collection of mite parasites of Australian frogs, reptiles, birds, and mammals is detailed. The data are largely restricted to new host records and major extensions of geographical range. The 48 species belong to the following 10 families: Blattisociidae 1, Ameroseiidae 1, Dermanyssidae 4, Spinturnicidae 1, Sarcoptidae 2, Teinocoptidae 1, Knemidokoptidae 1, Ereyneidae 1, Cheyletidae 1, and Trombiculidae 35.

Guntheria vegrandis, n. sp. (Trombiculidae), is described from *Rattus fuscipes* in South Australia.

Over the years, many series of mites have accumulated beyond the scope of current studies. Taken individually, these records may be minor, but as a whole they provide a useful body of confirmatory records and considerable extensions of known geographical and host ranges. Their publication as the first of an occasional series will both place these data on record and underline that the "rarity" of many species is due only to the desultory collecting of the past. Only extensive and intensive collecting over the entire continent will provide a full picture of the ranges and host spectra of the mites parasitic on Australian vertebrates.

In the following list, families are in systematic order, and genera and species in alphabetic order. For brevity, and since this is a largely non-taxonomic paper, generic documentation is not given, this being available in Neave (1939-66). All measurements are in micra. Hosts are largely given after Worrell (1963), Leach (1958) and Ride (1970), a skeleton classification of the hosts listed being:

AMPHIBIANS: Frogs (*Hyla*).

REPTILES: Snakes (*Liasis*), lizards (*Lygosoma*, *Varanus*).

BIRDS: Hawks (*Falco*), owls (*Ninox*, *Tyto*), frogmouths (*Podargus*), kingfishers (*Sauromartia*), swifts (*Collocalia*), perching birds (*Artamus*, *Chloris*, *Climacteris*, *Eopsaltria*, *Hylacola*, *Hylochelidon*, *Malurus*, *Meliornis*, *Meliphaga*, *Myzantha*, *Oriolus*, *Pachycephala*, *Pomatostomus*, *Sericornis*, *Struthidea*).

MAMMALS: Marsupials (*Antechinus*, *Cercartetus*, *Dasyurus*, *Isoodon*, *Macropus*, *Potorous*, *Schoinobates*, *Thylogale*, *Trichosurus*, *Vombatus*), rodents (*Melomys*, *Rattus*), bats (*Miniopterus*, *Pteropus*), carnivores (*Felis*), primates (*Homo*).

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Family BLATTISOCIIDAE

Genus PROCTOLAE LAP S Berlese

1. *Proctolaelaps pygmaeus* (Müller)

Gamasus pygmaeus Müller, 1859, *Z. Naturw.*, 9 : 29.

Garmania nesbitti Womersley, 1956, *J. Linn. Soc.*, 42 : 548. *New synonymy*.

Material. Many females causing annoyance, timber handlers, Brisbane, Qd, ix.1964, J.J.D.

Three females, *Rattus fuscipes*, Palmerston Highway, Qd, 3-10.xii.1963, G.J.B.

Notes. Hughes (1961) recorded this species both in association with mites of stored food products and as a free-living predator.

Family AMEROSEIIDAE

Genus KLEEMANNIA Oudemans

2. *Kleemannia plumosa* (Oudemans)

Seiulus plumosus Oudemans, 1902, *Tijdschr. Ent.*, 45 : 17.

Material. Several females, Weelawadji Cave, near Eneabba, W.A., 8.x.1972, J.L.

Notes. See notes above on *Proctolaelaps pygmaeus*.

Family DERMANYSSIDAE

Genus STRATIOLAE LAP S Berlese

3. *Stratiolaelaps miles* (Berlese)

Laelaps (Iphis) miles Berlese, 1892, *Acari, Myriapoda et Scorpiones hucusque in Italia reperta*, 63 : 9.

Cosmolaelaps scimitus Womersley, 1956, *J. Linn. Soc.*, 42 : 580. *New synonymy*.

Material. Two females, debris in total darkness in drains (inhabited by bats) in disused railway tunnel, Samford, Qd, 30.iv.1963, R.D. Three females, dark zone of Church Cave, Wee Jasper, N.S.W., 3.vi.1962, E.H-S.

Two females, *Collocalia vanicorensis*, Gatop, Finschhafen Subdistrict, New Guinea, x.1960, B.McM.

Notes. See notes above on *Proctolaelaps pygmaeus*.

Genus ICHORONYSSUS Kolenati

4. *Ichoronyssus miniopteri* (Zumpt and Patterson)

Neospinolaelaps miniopteri Zumpt and Patterson, 1952, *J. ent. Soc. sth. Afr.*, 15 : 159.

Material. Three females, *Miniopterus schreibersii*, Naracoorte, S.A., 23.ii.1963, E.H-S. One female, four males, and one protonymph, *Miniopterus tristis*, Iawarere Caves, 09° 29' S, 147° 38' E, Central District, Papua, 10.vii.1973, D.E.M. and G.W.

Notes. Although the population of *M. schreibersii* in the Naracoorte caves is isolated and biologically distinct from others in Australia, these specimens,

and those of *Macronyssus aristippe* below, are typical. On the other hand, *Spinturnix loricata* Domrow (Spinturnicidae) from this host at Naracoorte is very distinct from *S. psi* (Kolenati) on other populations (Domrow, 1972).

Genus MACRONYSSUS Kolenati

5. *Macronyssus aristippe* (Domrow)

Ichoronyssus aristippe Domrow, 1959, PROC. LINN. SOC. N.S.W., 83 : 228.

Material. Numerous specimens, *Miniopterus schreibersii*, Naracoorte, S.A., 5.xi.1961, 12.ii and 1.ix.1962, and 23.ii.1963, E.H.S. One female, *Miniopterus australis*, We Lifou Cave, New Caledonia, i.1963, W.H.A.

Notes. See notes above on *Ichoronyssus miniopteri*.

Genus OPHIONYSSUS Mégnin

6. *Ophionyssus natricis* (Gervais)

Dermanyssus natricis Gervais, 1844, *Hist. nat. Insectes apt.*, 3 : 223.

Material. Three females, *Liasis childreni*, Townsville, Qd, 24.vii.1966.

Notes. This species is a serious pest of snakes in captivity (Camin *et al.*, 1964), but the above new host was captured in the wild.

Family SPINTURNICIDAE

Genus MERISTASPIS Kolenati

7. *Meristaspis calcarata* (Hirst)

Ancystropus (Meristaspis) calcaratus Hirst, 1923, *Proc. zool. Soc. Lond.*, 1923 : 983.

Material. Four females, three males, and one deutonymph (plus material in spirit), *Pteropus tonganus geddiei*, Ipota, Eromanga, New Hebrides, 10.viii.1971, A.A. (The Royal Society and Percy Sladen Expedition to the New Hebrides, 1971).

Notes. This is a new host record (Domrow, 1972).

Family SARCOPTIDAE

Genus NOTOEDRES Railliet

8. *Notoedres muris* (Mégnin)

Sarcoptes notoedres var. *muris* Mégnin, 1877, *Revue Mag. Zool.*, (3) 5 : 71.

Material. Many specimens causing mange, *Trichosurus vulpecula*, Pomonal, Vic., 31.iii.1968.

Many specimens causing severe mange of head and forequarters, *Isoodon macrourus*, Paddington, Brisbane, Qd, 5.ix.1955, R.D.

Many specimens causing mange on ears and face, *Melomys cervinipes*, North Stradbroke Island, Qd, iii.1973, E.K.

Notes. These records indicate that this parasite, whose normal hosts are murid rodents, especially *Rattus norvegicus* (see Fain, 1968), can also establish itself on a variety of native species.

Genus SARCOPTES Latreille

9. *Sarcoptes scabiei* (Linnaeus)

Acarus Siro Scabiei Linnaeus, 1758, *Systema Naturae*. Holmiae : Laurentii Salvii, 616.

Material. Many specimens causing mange, *Vombatus ursinus*, Saint Mary's, Tas., 24.xi.1971, B.L.M.

Notes. See notes above on *Notoedres muris*.

Family TEINOCOPTIDAE

Genus TEINOCOPTES Rodhain

10. *Teinocoptes domrowi* Fain

Teinocoptes domrowi Fain, 1961, PROC. LINN. SOC. N.S.W., 85 : 269.

Material. Twenty females, *Pteropus scapulatus*, Mount Isa, Qd, ix.1966.

Notes. This is a new host record (Domrow, 1962b).

Family KNEMIDOKOPTIDAE

Genus KNEMIDOKOPTES Fürstenberg

11. *Knemidokoptes jamaicensis* Turk

Cnemidocoptes jamaicensis Turk, 1950 (*sic*), *Parasitology*, 40 : 60.

Material. Numerous specimens causing scaly-leg, *Chloris chloris*, Beaumont, S.A., 17.xii.1963, J.B.P.

Notes. This is a new host record (Fain and Elsen, 1967).

Family EREYNETIDAE

Genus LAWRENCARUS Fain

12. *Lawrencarus hylae* Fain

Lawrencarus hylae Fain, 1961, *Bull. Annl. Soc. r. ent. Belg.*, 97 : 247.

Material. One pallid adult inside mouth near entrances to nasal passages, *Hyla caerulea*, Kowanyama, Qd, 14.iii.1966, R.D. and P.A.G. (Four of six other *H. caerulea* with these data also harboured *L. hylae*, but the mites have been lost.)

Notes. The other known specimens from this host bear only the data Australia, 1880 (Fain, 1961).

Family CHEYLETIDAE

Genus CHELETONELLA Womersley

13. *Cheletonella vespertilionis* Womersley

Cheletonella vespertilionis Womersley, 1941, *Rec. S. Aust. Mus.*, 7 : 61.

Material. Three females, nest of *Hylochelidon ariel*, Richmond, N.S.W., B.McM.

Notes. This species is probably a nidophile rather than a true parasite—bats are well known to frequent the disused nests of this bird (Kaiser and Hoogstraal, 1973).

Family TROMBICULIDAE

Genus ASCOSCHOENGASTIA Ewing

14. *Ascoschoengastia lorius* (Gunther)

(Figs 1-8)

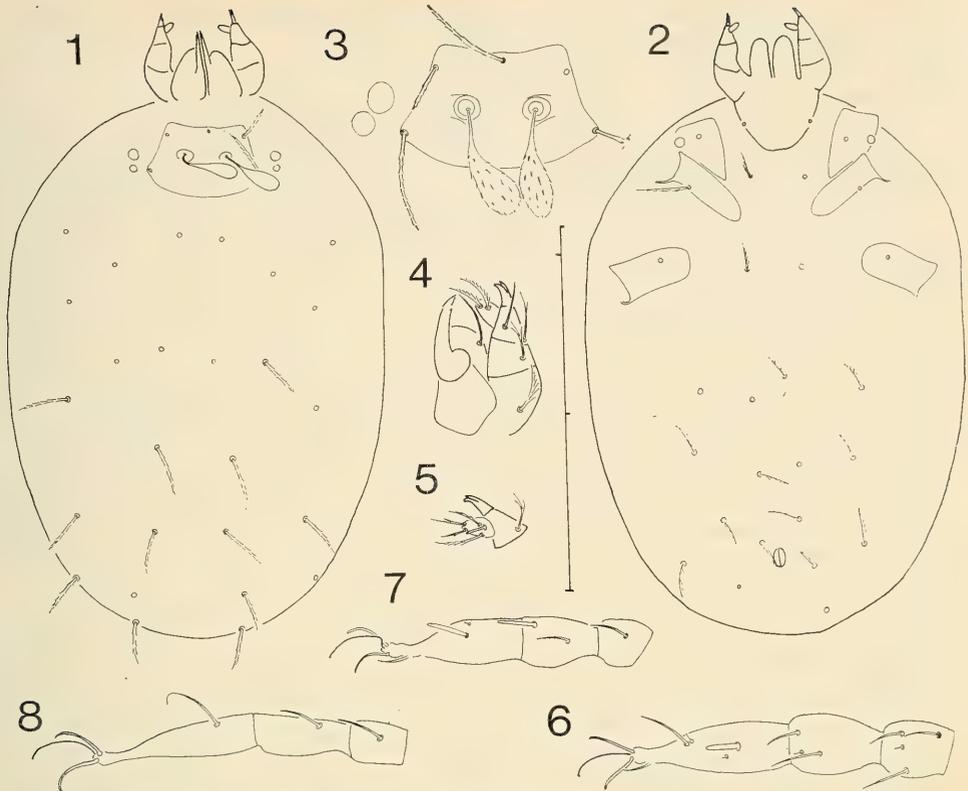
Neoschöngastia lorius Gunther, 1939, PROC. LINN. SOC. N.S.W., 64 : 86.

Euschöngastia daria Traub and Audy, 1954, *Stud. Inst. Med. Res. F.M.S.*, 26 : 81. *New synonymy.*

Material. Holotype and five paratypes, the only specimens remaining of the original series.

Notes. This little known species from a New Guinea parrot (*Lorius*) shows the following scutal measurements :

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	Specimen
43	61	22	20	22	42	22	—	18	35	36 × 10	Holotype
40	57	21	18	21	39	20	36	17	—	36 × 10	Paratype
42	57	22	18	23	41	—	32	17	—	35 × 11	"
42	59	22	20	21	41	20	34	17	34	38 × 10	"
39	56	21	18	20	38	22	—	—	35	35 × 10	"
41	58	22	19	21	40	21	34	17	35	36 × 10	—



Figs 1-8. *Ascoschoengastia lorius* larva. 1-2. Dorsal and ventral views of idiosoma (engorged). 3. Scutum and eyes. 4. Dorsal view of capitulum (cheliceral blade half turned and base foreshortened). 5. Ventral view of palpal tibiotarsus. 6-8. Specialized setation of legs I-III. (All drawn from holotype except Fig. 3; each division on scales=100 μ .)

15. *Ascoschoengastia rattus* (Womersley and Heaslip)

Neoschoengastia rattus Womersley and Heaslip, 1943, *Trans. R. Soc. S. Aust.*, 67: 118.

Material. Three larvae, *Trichosurus vulpecula*, Kelso, Tas., 16.ii.1961, B.C.M.

Notes. The scutal measurements of two of these specimens are:

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
35	51	17	20	20	40	30	25	12	35	34×8
33	53	19	20	20	40	28	23	12	36	35×8
34	52	18	20	20	40	29	24	12	36	34×8

This is a new host record (Nadchatram and Domrow, 1964).

Genus EUTROMBICULA Ewing

16. *Eutrombicula hirsti* (Sambon)

Trombicula hirsti Sambon, 1927, *Ann. Mag. nat. Hist.*, (9) 20: 157.

Material. Several attached larvae, forestry workers, Gin Gin, Qd, 16.ii.1971, K.R.

Notes. Previous records of this itch mite in Australia have been from North Queensland (Domrow, 1962*b*, 1967*b*).

17. *Eutrombicula macropus* (Womersley)

Trombicula macropus Womersley, 1936, *J. Linn. Soc.*, 40 : 112.

Material. Seven larvae attached to inner surface of knee, *Macropus giganteus*, Kowanyama, Qd, 25.x.1966, R. D. Eighteen larvae attached inside ear, *Macropus agilis*, Kowanyama, Qd, 25-26.x.1966, R.D.

Notes. This is the first record of this species since the original series from *Macropus*, Darwin, N.T., 1934.

18. *Eutrombicula tovelli* (Womersley)

Trombicula (? *Neotrombicula*) *tovelli* Womersley, 1952, *Rec. S. Aust. Mus.*, 10 : 116.

Material. Eleven larvae, *Varanus varius*, Eidsvold, Qd, 25.xi.1960, M.J.M. Eleven larvae, skink, Lower Ballunju, Lamington Plateau, Qd, 12.ii.1964, L.C. Twenty-two larvae attached in axillae and inguina, *Lygosoma fuscum*, Kowanyama, Qd, 14.iii.1966, R.D. and P.A.G. Three larvae, *Lygosoma challengerii*, Springbrook, Qd, 10.ii.1955, E.N.M.; nine larvae attached in axillae, *L. challengerii*, Canungra, Qd, iii.1971, R.D. and R.W.C.

Notes. These new host records confirm the preference of this species for lizards.

Genus GUNTHERIA Womersley

19. *Guntheria alpina* (Domrow)

Guntherana alpina Domrow, 1964, *Acarologia*, 6 : 327.

Material. Nine larvae, *Rattus fuscipes*, Tommy's Bend, Vic., 10.ii.1963, R.M.W.; five larvae, *R. fuscipes*, Mount Macedon, Vic., 18.xii.1963, R.M.W.; two larvae, *R. fuscipes*, Rifle Range, Pomborneit, Vic., 17.xii.1964, R.M.W.

Notes. These specimens, all from far south-eastern Australia, confirm the original record from Mount Kosciusko, N.S.W.

20. *Guntheria antipodiana* (Hirst)

Schöngastia antipodianum Hirst, 1929 (*sic*), *Proc. zool. Soc. Lond.*, 1929 : 175.

Material. Several larvae, *Rattus fuscipes*, Mount Magnificent, S.A., 20.vii.1970, R.A.

Notes. These specimens, from the type host, are virtually topotypic.

21. *Guntheria cassiope* (Womersley)

Schöngastia (*Ascöschöngastia*) *cassiope* Womersley, 1952, *Rec. S. Aust. Mus.*, 10 : 187.

Material. One larva attached at base of underside of bill, *Meliornis novae-hollandiae*, road from Bulli to Appin, N.S.W., 26.vii.1967, H.B.

Many larvae attached inside ears, *Rattus sordidus*, Kowanyama, Qd, iv.1969, R.D. and E.T.B. Twenty larvae attached inside ears, *Rattus leucopus*, Dayman Point, Qd, 12-19.vi.1970, R.D. and R.W.C.

Notes. See notes below on *Guntheria coorongensis* and *Leptotrombidium deliense* with reference to the first two series. The third is a new host record.

22. *Guntheria coorongensis* (Hirst)

Schöngastia coorongense Hirst, 1929 (*sic*), *Ann. Mag. nat. Hist.*, (10) 3 : 565.

Material. Three larvae attached around cloaca, *Hylacola pyrrhopygia*, four miles west of Pairy Meadow, N.S.W., 27.xii.1967, H.B. Seventy larvae attached mostly around cloaca, but also on head and abdomen, and among

scapulars and retrices, *Sericornis frontalis*, near Fairy Meadow, N.S.W., 27.xii.1967, 29.i.1968, 24.ii.1968, 26.iii.1967, 16.iii.1968, and 13-15.iv.1968, H.B. ; three larvae, *S. frontalis*, Cordeaux Dam, N.S.W., 29.iii.1969, H.B. Two larvae, *Malurus cyaneus*, one mile west of Keira, N.S.W., 21.v.1972, H.B. Nine larvae attached around cloaca, *Meliornis novaehollandiae*, four miles west of Fairy Meadow, N.S.W., 13.iii.1967, H.B.

Several larvae, *Antechinus stuartii*, near Melbourne, Vic., 29.vii.1972, R.S. ; two larvae, *A. stuartii*, Powelltown, Vic., 20.viii.1973, I.B.

Seven larvae, *Rattus fuscipes*, Pearl Beach, N.S.W., 4.i.1955, B.E.H. and J.M.T. ; many larvae, *R. fuscipes*, Bat's Ridge, Vic., 19-25.i.1968, J.H.S. ; many larvae, *R. fuscipes*, Bemm River and Bonang, Vic., 21-27.ii.1968, J.H.S. and R.T. ; several larvae, *R. fuscipes*, Dargo Road near Mount Saint Bernard, Vic., 14.ii.1967, K.J.C. ; several larvae, *R. fuscipes*, Otway Ranges, Vic., 13.iv.1968, J.H.S. ; several larvae, *R. fuscipes*, Heathmere, Vic., 22.vii.1968, J.H.S. ; several larvae, *R. fuscipes*, Rifle Range, Pomborneit, Vic., 17.xii.1964, R.M.W. Many larvae, *R. fuscipes*, Carey's Gully, Mount Lofty, S.A., vi-vii.1969, J.C. and B.P. ; several larvae, *R. fuscipes*, Mount Magnificent, S.A., 20.vii. 1970, R.A. ; two larvae, *R. fuscipes*, Kangaroo Island, S.A., ii.1969, S.H.W. Several larvae, *Rattus lutreolus*, Bemm River, Vic., 26.ii.1968, R.T. ; several larvae, *R. lutreolus*, The Grampians, Vic., 28.iv.1968, J.H.S. ; several larvae, *R. lutreolus*, Healesville Sanctuary, Vic., 20-21.viii.1964, R.M.W.

Notes. Two considerable collections of chiggers from small ground mammals in north Queensland (Domrow, 1962*b*, 1967*b*) yielded large numbers of *Guntheria* spp., but only one species—*G. innisfailensis* (Womersley and Heaslip), see Domrow (1960*a*)—was recorded from a bird until Brennan (1965) and Brennan and Amerson (1971) consistently obtained *G. domrowi* (Brennan) from various waders in the central Pacific. The present records (and those of *G. cassiope* above and *G. pannosa* below) indicate birds are regular, if minor, hosts for *Guntheria* spp.

The specimens from South Australia may be regarded as topotypes, the species having been originally described from Robe.

23. *Guntheria derricki* (Womersley)

Neoschongastia derricki Womersley, 1939, *Trans. R. Soc. S. Aust.*, 63 : 162.

Neoschongastia similis Womersley and Heaslip, 1943, *Trans. R. Soc. S. Aust.*, 67 : 124. *New synonymy.*

Guntherana (Derrickiella) rex Domrow, 1960, *Pacif. Insects*, 2 : 212. *New synonymy.*

Material. Thirteen larvae, *Antechinus stuartii*, Condor Creek, A.C.T., 26.ii.1964, P.A.W. Five larvae, *Antechinus swainsonii*, above Silverband Falls, The Grampians, Vic., 3.xi.1962, R.M.W.

One larva, *Rattus fuscipes*, Pearl Beach, N.S.W., 4.i.1955, B.E.H. and J.M.T. ; 10 larvae, *R. fuscipes*, Bat's Ridge, Vic., 21.i.1968, J.H.S.

Notes. Domrow (1960*a*), while noting minor variation, maintained the above three nominal taxa ; more extensive collections, however, indicate synonymy. *G. similis* normally shows DS commencing 2.4.4, though 2.5.4 was noted once and 2.6.4 13 times. *G. derricki* normally shows 2.6.6, but this pattern is not uncommon (I can only say "not uncommon" since these specimens were deliberately selected) in long series that can only be assigned to *G. rex* (73 random specimens of which show 2.8.8 in 21, 2.8.7 in 19, 2.8.6 in 30, and 2.7.6 in three specimens).

The present series, the first collected outside Queensland, are also best assigned here. All are typical of *G. derricki* except that from Condor Creek. Here, the DS commence 2.8 in four, 2.9 in two, 2.10 in six, and 2.11 in one

specimen. It is difficult to decide the number of setae in the next row, but 8-10 is a fair approximation. Typical specimens have the following scutal standard data in micra :

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
66	85	33	26	22	48	17	61	29	90	—
72	89	37	24	25	49	17	59	29	77	—
65	81	31	23	23	46	16	58	24	82	—
64	82	33	24	24	48	14	64	25	88	—
67	85	34	24	25	49	16	60	29	90	—
67	85	37	24	25	49	16	61	29	87	39×18
67	84	34	24	24	48	16	60	28	86	39×18

24. *Guntheria kallipygos* (Gunther)

Neoschöngastia kallipygos Gunther, 1939, PROC. LINN. SOC. N.S.W., 64 : 83.

Material. Eight larvae attached to reddened, slightly scabby area on inner surface of thigh, *Macropus giganteus*, Yan Yean, Vic., x.1972, J.H.A.

One larva, *Trichosurus vulpecula*, Kelso, Tas., 16.ii.1961, B.C.M.

Notes. Previous records of this species are from New Guinea to south-eastern Queensland (Womersley, 1952 ; Domrow, 1961).

25. *Guntheria newmani* (Womersley)

Schöngastia (Ascoshöngastia) newmani Womersley, 1952, *Rec. S. Aust. Mus.*, 10 : 427.

Material. The syntype slide—this contains 16 over-cleared specimens.

Twenty-six larvae, *Cercartetus nanus*, Yackandandah, Vic., 23.iii.1965, R.M.W.

Five larvae, *Antechinus flavipes*, Tarago, near Goulburn, N.S.W., 29.iii.1970, N.R. ; 14 larvae, *A. flavipes*, Mundaring Road two miles from Kalamunda, W.A., 10.iv.1963, P.A.W. Ten larvae, *Antechinus stuartii*, Pearl Beach, 30 miles north-east of Sydney, N.S.W., 26.vii.1955, B.E.H. and J.M.T. ; one larva, *A. stuartii*, Paddy's River, A.C.T., 19.iv.1964, K.K. ; five larvae, *A. stuartii*, Mallacoota, Vic., 23.viii.1965, J.W.

Eight larvae, *Rattus rattus*, Pomonal, Vic., 2.iv.1968, J.H.S.

Seven larvae attached to ear, domestic cat, Shenton Park, W.A., 25.i.1973, G. de C.

Notes. Interestingly, the only other known series is also from a domestic cat (Western Australia, 1931).

26. *Guntheria pannosa* (Domrow)

Guntherana (Guntherana) pannosa Domrow, 1960, *Pacif. Insects*, 2 : 225.

Material. One larva attached among retrices, *Sericornis frontalis*, Mount Keira, N.S.W., 13.i.1968, H.B.

Notes. The only other known specimen of this species is from North Queensland.

27. *Guntheria peregrina* (Womersley)

Schöngastia (Ascoshöngastia) peregrina Womersley, 1952, *Rec. S. Aust. Mus.*, 10 : 220.

Material. Three paratypes.

Twenty-two larvae, *Schoinobates volans*, Esk-Toogoolawah district, Qd, 8.ii.1964, R.D. and I.D.F.

Eight larvae, *Antechinus bellus*, Victoria, Port Essington, N.T., 10.vii.1965, J.H.C. ; 15 larvae, *A. bellus*, Mount Brockman Range, N.T., 11.vii.1972, T.O.W.

Notes. The only other known series of this species is from North Queensland.

28. *Guntheria philippensis* (Philip and Woodward)

Neoschongastia philippensis Philip and Woodward, 1946, *Am. J. trop. Med.* 26 : 158.

Material. About 20 larvae, *Isoodon macrourus*, Nourlangie Camp, South Alligator River, N.T., 17.viii.1962, J.H.C.

Notes. These specimens, and their scutal measurements, fit the original description so closely that the presence of this species in Australia can no longer be doubted (Domrow, 1960a, 1961).

Scutal standard data in micra of G. philippensis

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
48	69	19	21	12	33	21	25	42	42	—
53	73	18	21	13	34	22	22	41	—	—
49	66	20	22	12	34	22	24	37	46	—
49	68	19	20	11	31	21	25	43	43	—
43	66	16	20	10	30	21	24	40	—	—
50	75	20	20	12	32	22	24	—	45	25 × 16
49	70	19	21	12	32	22	24	41	44	25 × 16

29. *Guntheria quatuor* Domrow

Guntheria quatuor Domrow, 1972, *J. Aust. ent. Soc.*, 11 : 103.

Material. Several larvae, *Rattus fuscipes*, Bat's Ridge, Vic., 19–25.i.1968, J.H.S. ; several larvae, *R. fuscipes*, Kalorama, Dandenong Ranges, Vic., 18.ii.1965, J.H.S. ; several larvae, *R. fuscipes*, Bemm River and Bonang, Vic., 21–26.ii.1968, J.H.S. and R.T. ; one larva, *R. fuscipes*, Rifle Range, Pomborniet, Vic., 17.xii.1964, R.M.W. Two larvae, *Rattus lutreolus*, Bemm River, Vic., 26.ii.1968, R.T.

Notes. Although this species was described from Western Australia, the present series show all three diagnostic characters (entire sensillary insertions in front of PL, six setae in first row of DS, and three genualae I), and the following minor deviations from the original description are therefore considered to fall within the range of intraspecific variation : AM > AL (the opposite is true of the type series) ; galeal setae with one-three branches (but occasionally nude as in the type series) ; dorsal palpal tibial seta nude (in the type series, this seta may be so lightly branched as to appear virtually nude).

Scutal standard data in micra of G. quatuor

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
57	81	17	33	16	49	38	57	46	69	35 × 20
59	80	17	33	16	49	41	50	53	72	34 × 18
63	86	20	30	13	43	37	53	49	73	36 × 17
60	83	17	32	13	45	39	57	43	72	36 × 20
61	85	20	33	13	46	37	54	43	71	33 × 19
64	86	20	32	14	46	39	58	46	73	36 × 20
—	—	—	—	—	—	—	57	49	72	—
—	—	—	—	—	—	—	58	48	80	—
—	—	—	—	—	—	—	59	51	74	—
—	—	—	—	—	—	—	53	49	67	—
61	84	18	32	14	46	38	56	48	72	35 × 19

30. *Guntheria queenslandica* (Womersley)

Neoschongastia queenslandica Womersley, 1939, *Trans. R. Soc. S. Aust.*, 63: 162.

Material. Numerous specimens, domestic cat, Colo Vale, N.S.W., 15.viii.1960, A.L.D.

Notes. This is a new host record, but Domrow (1960a) recorded the species from this locality on rabbits.

31. *Guntheria shieldsi* (Gunther)

Neoschöngastia shieldsi Gunther, 1941, *PROC. LINN. SOC. N.S.W.*, 66: 158.

Material. One larva, *Cercartetus nanus*, Yackandandah, Vic., 23.iii.1965, R.M.W.

Two larvae, *Antechinus stuartii*, near Melbourne, Vic., 29.viii.1972, R.S.

Notes. Previous records of this species are from New Guinea and Queensland (Domrow, 1960a).

32. *Guntheria smithi* (Womersley)

Neoschongastia smithi Womersley, 1939, *Trans. R. Soc. S. Aust.*, 63: 164.

Material. Ten larvae, *Rattus leucopus*, Dayman Point, Qd, 16.vi.1970, R.D. and R.W.C.

Notes. This is a new host record (Domrow, 1962b, 1967b).

33. *Guntheria vegrandis*, n. sp.

(Figs 9–15)

Diagnosis. *G. vegrandis* belongs in the subgenus *Derrickiella* Audy and Domrow (see Domrow, 1960a), and keys out near *G. dumosa* (Womersley, 1952). The latter species, however, shows stout, stiffly barbed dorsal setae, a convex posterior scutal margin, subglobose sensillae, and tarsala I set distally, almost level with the subterminala. The new species has a biconvex posterior scutal margin as in *G. coorongensis*, but is readily separable in that the dorsal setae commence 2.10.10.10 rather than 2.6.6.6.

Types. Holotype and nine paratype larvae attached inside ears, *Rattus fuscipes*, Carey's Gully, Mount Lofty, S.A., vi and vii.1969, J.C. and B.P. Holotype and three paratypes in Australian National Insect Collection; six paratypes in Queensland Institute of Medical Research.

One larva (not a type), *Antechinus stuartii*, Powelltown, Vic., 23.vii.1973, I.B.

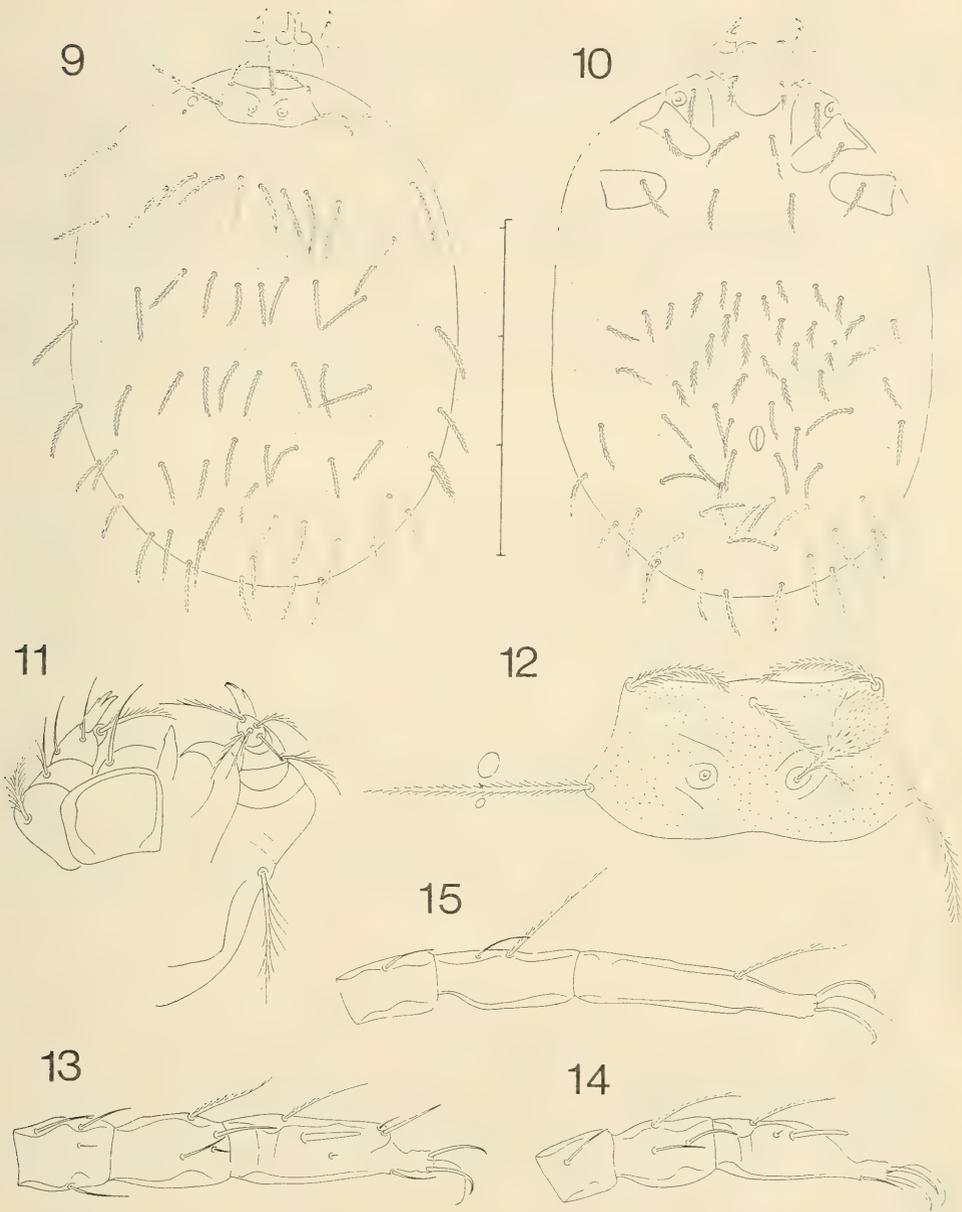
Larva. Palpi of usual proportions, with three-pronged tibial claws. Setation B.b.nmb.5B+T; subterminala absent. Capitular setae two, well branched. Galeal setae nude. Chelicerae unarmed except for usual tricuspid cap; bases appearing foreshortened in all specimens, but without obvious posterolateral expansions.

Body with annulate cuticle. Dorsal setae arranged

2.10(11,12).10(11,12).10(11)+28.

Intercoxal setae 2+2. Ventral setae 60.

Scutum with anterior margin sinuous, lateral margins slightly concave, and posterior margin biconvex. Surface lightly punctate except behind AM and SB. PL, AM, AL, with PL and AL set on distinct corners, and AM well behind margin. Sensillae spiculate, clavate, and set slightly in front of PL. Eyes 2+2, but weak, particularly posterior pair.



Figs 9-15. *Guntheria vegrandis* larva. 9-10. Dorsal and ventral views of idiosoma (engorged). 11. Dorsal and ventral views of capitulum (cheliceral base foreshortened). 12. Scutum and eyes. 13-15. Specialized setation of legs I-III. (Each division on the scales = 100 μ .)

Scutal standard data in micra of G. vegrandis

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
74	94	28	29	20	49	33	44	41	67	35×17
74	95	29	29	20	49	32	48	—	66	34×18
73	90	29	27	20	47	30	45	38	67	—
71	90	27	—	—	—	—	48	—	72	37×16
74	93	30	31	19	50	32	48	—	72	—
74	90	29	31	20	51	35	50	42	72	—
73	92	29	29	20	49	32	47	40	69	35×17

Leg I with pretarsala, subterminala, parasubterminala, tarsala and microtarsala; two tibialae and microtibiala; three genualae and microgenuala. Leg II with pretarsala, tarsala and microtarsala; two tibialae; genuala. Leg III with tibiala; genuala. Coxae 1.1.1 (two paratypes show two setae on coxa III on one side; the specimen from *Antechinus* shows two setae on both coxae III); trochanters 1.1.1; basifemora 1.2.2; telofemora 5.4.3; genua 4.3.3; tibiae 8.6.6; tarsi not counted (of these barbed setae, none are unduly long and outstanding). All tarsi with two simple claws and empodium.

Notes. The specific name is a Latin adjective (*vegrandis*, not very large), and refers to the diminutive eyes.

Genus LEPTOTROMBIDIUM Nagayo *et al.*34. *Leptotrombidium akamushi* (Brumpt)

Trombidium akamushi Brumpt, 1910, *Précis de Parasitologie*. Paris: Masson & Cie, 506.

Material. Several larvae, *Rattus exulans*, Nendo Island, Santa Cruz, Solomon Islands, J.A.R.M.

Notes. These typical specimens confirm the known limit of this essentially Asian vector of scrub typhus (Womersley, 1952). The disease occurs still further south-east in the New Hebrides, where the vector is inferred to be *L. deliense*, the following species (Audy, 1961).

Fortunately, Philip's proposal (1961) now before the International Commission on Zoological Nomenclature to validate this name is not compromised by Vercaemmen-Grandjean's (1969) selection of a "lectotype"—though his formal designation on page 100 reads "holotype"—in circumstances that demand a neotype (see Articles 74 and 75).

35. *Leptotrombidium deliense* (Walch)

Trombicula deliensis Walch, 1922, *Geneesk. Tijdschr. Ned.-Indië*, 62: 552.

Material. Two larvae attached inside ear, *Rattus sordidus*, Belbora, Kowanyama, Qd, iv.1969, R.D. and E.T.B.

Notes. An unexpected record. Previous Australian material was all from the eastern side of Cape York Peninsula, normally in tropical vegetation (particularly rain forest) with over 60 inches of rain per year. Kowanyama is on the western side of the Peninsula, but watered by the Mitchell River, which rises far to the east. The annual rainfall is only about 45 inches, almost all of which falls in a circumscribed "wet" (December–March); the "dry" (April–November) is characterized by heat and very low humidity (Domrow, 1967a). However, both infested rats were collected in tall grass close to dense undergrowth under a clump of mango trees along the banks of permanent pools at Belbora. A situation not unlike this was noted at Rocky Creek, Qd, described by Barrow, Domrow and Derrick (1963).

36. *Leptotrombidium myzantha* (Womersley)

Trombicula (*Leptotrombidium*) *myzantha* Womersley, 1952, *Rec. S. Aust. Mus.*, 10 : 71.

Material. Six larvae, *Falco cenchroides*, Kowanyama, Qd, iv.1969, R.D.

Numerous larvae, *Ninox novaeseelandiae*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S. Numerous larvae, *Ninox connivens*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S. Numerous larvae, *Tyto alba*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S.

Numerous larvae, *Podargus strigoides*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S.; six larvae, *P. strigoides*, Mudginberri, N.T., 31.iii.1971, A.L.D. and H.A.S. Numerous larvae, *Podargus papuensis*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S.

Ten larvae, *Pomatostomus temporalis*, Condamine, Qd, 12.i.1966, R.D., D.J.M. and J.S.W. Two larvae, *Pachycephala rufiventris*, Charleville, Qd, 18.i.1966, R.D., D.J.M. and J.S.W. Three larvae, *Meliphaga flava*, Kowanyama, Qd, 25.x.1965, R.D. Five larvae, *Myzantha melanocephala*, Condamine, Qd, 12.i.1966, R.D., D.J.M. and J.S.W. Ten larvae, *Struthidea cinerea*, Condamine, Qd, 12.i.1966, R.D., D.J.M. and J.S.W.

Notes. Previous records (Gill, Moule and Riek, 1945; Domrow, 1966) are from a wide variety of passeriform birds. The present series, however, are largely from non-passeriform predators (one diurnal kestrel and five species of nocturnal owls and frogmouths). Almost all of more than 30 predators examined were infested, the number of chiggers per bird ranging up to 1,800. There was a light admixture (5–10%) of a second bird-specific chigger, *Neoschoengastia americana* (see below), the infestations doubtless having been acquired while taking prey in dense grassland under open sclerophyll forest.

Scutal standard data in micra of *L. myzantha*

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
70	76	22	30	15	45	32	33	40	56	56
66	76	22	27	16	43	29	30	37	58	—
73	81	24	27	16	43	30	30	36	56	56
75	85	25	32	17	49	31	37	42	59	64
67	77	22	27	17	44	29	35	41	56	58
69	78	—	—	—	—	29	—	41	54	—
70	79	23	29	16	45	30	33	40	56	58

37. *Leptotrombidium robustum* (Gunther)

(Figs 16–22)

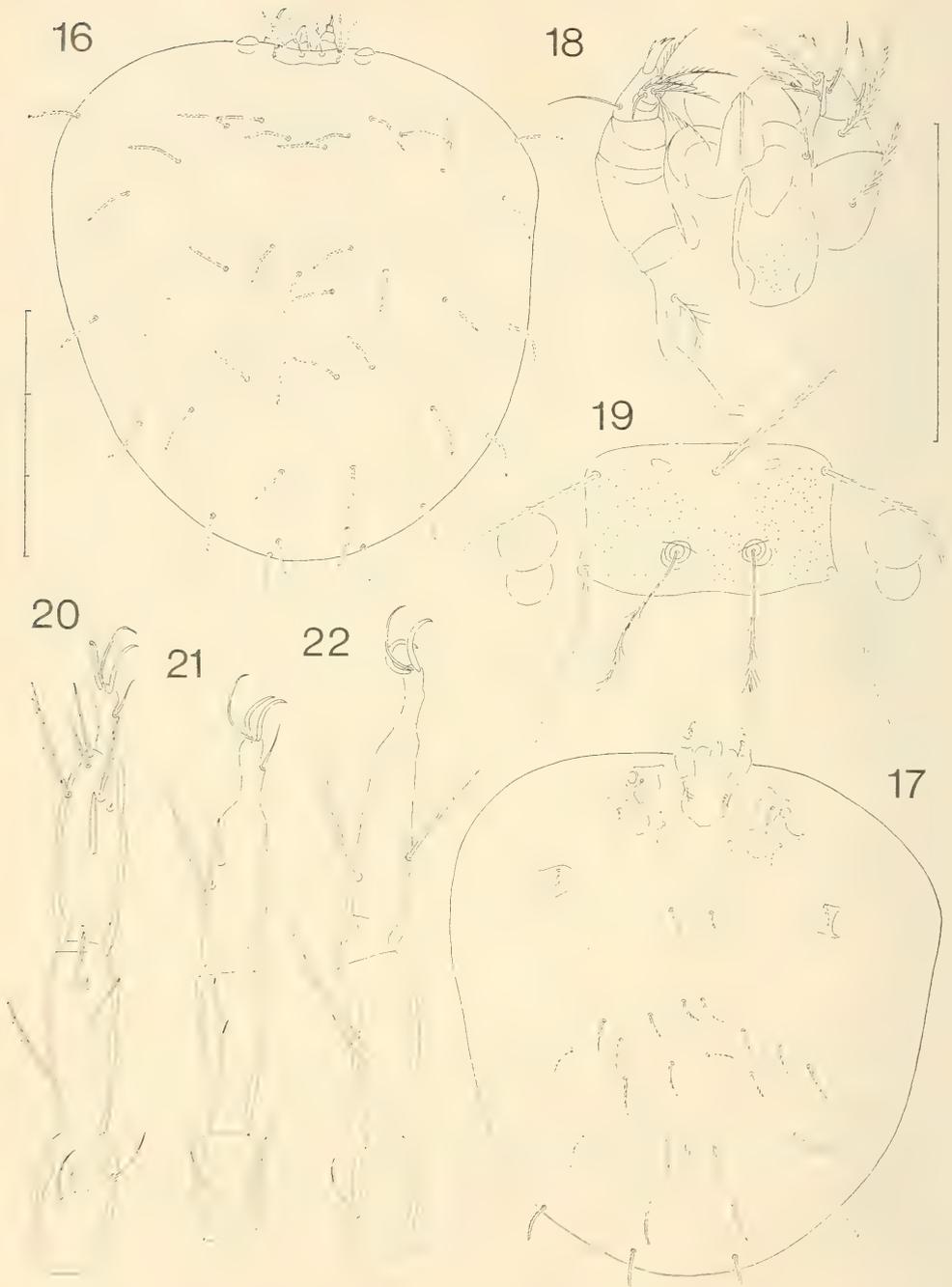
Trombicula robusta Gunther, 1941, *PROC. LINN. SOC. N.S.W.*, 66 : 157.

Material. Holotype and one paratype, the only specimens remaining of the original series from Bulolo, New Guinea (on the same slide, with holotype not differentiated and host not indicated).

Fourteen larvae, *Sauromarptis gaudichaud*, Vanimo, New Guinea, 25.iv.1965, W.B.H.

One larva, *Podargus strigoides*, Mudginberri, N.T., 31.iii.1971, A.L.D. and H.A.S.

Notes. This little known species belongs to a group of bird chiggers which engorge heavily, leaving the vertically orientated scutum almost impossible to examine. Thus only one of the type series and one of the 14 from Vanimo are measurable.



Figs 16-22. *Leptotrombidium robustum* larva. 16-17. Dorsal and ventral views of idiosoma (enlarged). 18. Dorsal and ventral views of capitulum. 19. Scutum and eyes. 20-22. Specialized setation of legs I-III. (Each division on the scales = 100 μ .)

The Mudginberri specimen was taken with *L. myzantha* (see above), but shows DS 2.10.8.6.4.2.2 and VS 17.4.4.2. This compares better with the counts for specimens from Vanimo, which show DS 2.10-13.8-12.8-10.4-6.2.2 (av. 2.12.10.8.4.2.2), VS 12-15.4.4.2. The usual count for DS in *L. myzantha* is only 2.8.6.6.4.2.2. The scutal measurements of this specimen also compare better with undoubted specimens of *L. robustum* than with *L. myzantha*.

Scutal standard data in micra of L. robustum

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	Locality
73	81	25	31	13	44	30	42	48	52	50	Bulolo
73	77	23	34	13	47	31	48	49	57	51	Vanimo
77	81	25	34	16	50	33	49	49	58	64	Mudginberri
74	80	24	33	14	47	31	46	49	56	55	

I have placed this and the preceding species as conservatively as possible, noting that the nymph as well as the larva of Womersley's species is very similar to those of *Leptotrombidium* (see Domrow, 1957, 1960*b*; Nadchatram, 1967).

The plethora of taxa proposed for various members of this complex—*Toritrombicula* Sasa, Hayashi and Kawashima, *Vorcana* Audy, *Tsutsugamushia* Asanuma, *Cotrombidium* Vercammen-Grandjean, *Neacariscus* Vercammen-Grandjean, *Whartonacarus* Vercammen-Grandjean, and *Toriacarus* Vercammen-Grandjean and André (the lattermost with the same nominal type-species as *Cotrombidium*)—prompts some comment on recent trends in trombiculid taxonomy.

Complicated tables of genus-group taxa have been proposed, based essentially on the sensory setation of the larval appendages, with no attention to post-larval stages, and all characters equally weighted. This rigidity, coupled with a lack of attention to convergent (adaptive) characters and parallelism, has led to taxa containing species mismatched zoogeographically.

Further, it is implicit in this method that taxa may be validly defined by differences. But even Linnaeus saw that one cannot first choose a set of characters, and then decide that all species showing them are congeneric. It is the genus that dictates the characters, and the taxonomist must first recognize natural groups of species and then decide which characters diagnose the genus.

The former approach leads to a certain logicity, though two unfortunate aspects are the prediction of hypothetical groups and their subsequent proliferation as extremely small taxa. Any resulting system may be useful in that it is practical, but the natural (phylogenetic) classification we still lack will be based on degrees of similarity between taxa.

Genus NEOSCHOENGASTIA Ewing

38. *Neoschoengastia americana* (Hirst)

Schöngastia americana Hirst, 1921, *Ann. Mag. nat. Hist.*, (9) 7 : 37.

Neoschöngastia americana solomonis Wharton and Hardcastle, 1946, *J. Parasit.*, 32 : 292. *New synonymy*.

Paraschöngastia thomasi Radford, 1946, *Proc. zool. Soc. Lond.*, 116 : 262. *New synonymy*.

Neoschöngastia entomyza Womersley, 1952, *Rec. S. Aust. Mus.*, 10 : 265. *New synonymy*.

Material. One paratype of *N. entomyza*.

Numerous larvae, *Ninox novaeseelandiae*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S. Numerous larvae, *Ninox connivens*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S.

Numerous larvae, *Podargus papuensis*, Kowanyama, Qd, iv.1969, R.D., A.L.D. and H.A.S.

One larva, *Pomatostomus temporalis*, Condamine, Qd, 12.i.1966, R.D., D.J.M. and J.S.W. One larva, *Artamus minor*, Kowanyama, Qd, 27.iv.1969, A.L.D. Fifteen larvae, *Pachycephala rufiventris*, Charleville, Qd, 18.i.1966, R.D., D.J.M. and J.S.W. One larva, *Struthidea cinerea*, Condamine, Qd, 12.i.1966, R.D., D.J.M. and J.S.W.

Notes. In all clear specimens, including the paratype, the long outstanding seta on tarsus III is distinctly ciliated, the sternal setae are arranged 2+2, and the DS 2.8.6.4.6.4.2. A few specimens from Charleville show only six setae in the first dorsal row, but are clearly conspecific (see Brennan, 1951). Likewise, Malayan material with intercoxal setae 2+4 (Domrow and Nadchatram, 1960) is retained here.

Scutal standard data in micra of N. americana

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	Locality
43	62	26	22	26	48	33	35	46	45	29×16	Kowanyama
46	67	—	23	34	57	35	34	42	42	—	"
40	64	25	19	32	51	29	33	—	48	—	"
45	61	28	16	34	50	27	34	43	43	30×17	"
43	65	22	25	27	52	30	—	35	50	—	Charleville
41	60	25	18	27	45	32	28	37	46	17	"
43	67	25	21	25	46	27	—	37	45	—	Condamine
43	64	25	21	29	50	30	33	40	46	30×17	

39. *Neoschoengastia posekanyii* Wharton and Hardcastle

Neoschöngastia posekanyii Wharton and Hardcastle, 1946, *J. Parasit.*, 32 : 302.

Material. Fifteen larvae attached to sternum, *Eopsaltria australis*, Bulli, N.S.W., 2.iii.1968, H.B. Four larvae attached to abdomen, *Sericornis lathamii*, Bulli, N.S.W., 1.i.1968, H.B. Seven red-orange larvae attached in opening of swellings on skin near cloaca, *Sericornis frontalis*, Bulli Pass, N.S.W., 31.xii.1966, P.D.S. Four red-orange larvae attached in opening of swelling on skin caudal to sternum on brood pouch, *Pachycephala pectoralis*, Bulli Pass, N.S.W., 1.i.1967, P.D.S.; one larva attached to abdomen, *P. pectoralis*, four miles west of Fairy Meadow, N.S.W., 26.iii.1967, H.B. One red-orange larva attached in opening of swelling on skin caudal to sternum on brood pouch, *Meliphaga lewinii*, Bulli Pass, N.S.W., 1.i.1967, P.D.S.; 18 larvae attached near cloaca, *M. lewinii*, Bulli, N.S.W., 1.i.1968, H.B. Five deep orange larvae attached to bare patch of skin on abdomen, *Meliornis novaehollandiae*, near Mount Keira, N.S.W., 4.ii.1967, H.B. Twelve larvae, *Oriolus sagittatus*, Esk, Qd, 13.ii.1968, R.D. and B.H.K.

Notes. These are all new host records (Domrow 1966).

Genus NEOTROMBICULA Hirst

40. *Neotrombicula antechinus* (Womersley)

Trombicula antechinus Womersley, 1954, *Trans. R. Soc. S. Aust.*, 77 : 69.

Material. Several larvae, *Antechinus stuartii*, Mount Nebo, Qd, 3.viii.1966, R.H.W.

Several larvae, *Rattus fuscipes*, Mount Glorious, Qd, ix and x.1955, R.D.

Notes. Scutal measurements (including a seta from the first dorsal row) of this topotypic material indicate that the shallowness of the posterior scutal margin (PSB 19) figured by Womersley is real, and the species is therefore maintained.

Scutal standard data in micra of N. antechinus

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	DS
70	86	27	31	21	52	30	54	—	52	93	53
64	87	29	32	19	51	32	45	—	50	95	45
62	81	29	32	17	49	30	45	40	—	96	49
64	83	27	32	19	51	30	45	—	51	—	49
63	82	26	32	19	51	32	—	38	43	—	46
61	82	27	33	20	53	33	46	43	46	90	45
64	84	28	32	19	51	31	47	40	48	94	48

41. *Neotrombicula comata* Domrow

Neotrombicula comata Domrow, 1961, PROC. LINN. SOC. N.S.W., 86 : 82.

Material. One larva attached to abdomen, *Sericornis frontalis*, Mount Keira, N.S.W., 24.ix.1967, H.B. One larva, *Climacteris leucophaea*, Mount Keira, N.S.W., 24.ix.1967, H.B.

Many larvae, *Macropus parma*, Doyle's River State Forest, 45 miles north-west of Wauchope, N.S.W., viii.1973, G.M.M.

One larva, *Dasyurus maculatus*, Bessiebelle, Vic., 28.vii.1964, R.J. Five larvae, *Antechinus stuartii*, near Melbourne, Vic., 29.viii.1972, R.S. One larva, *Antechinus swainsonii*, Sherbrooke Forest, Dandenong Ranges, Vic., 4.vii.1966, R.M.W.

Eight larvae, *Rattus fuscipes*, Heathmere, Vic., 22-24.vii.1968, J.H.S.

Notes. The only previous record is from a bandicoot (*Perameles*) in northern New South Wales. The present specimens agree closely with the original description, the DS commencing 2.12-16.10-14. Average scutal measurements are given below.

Scutal standard data in micra of N. comata

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	Host
79	98	30	35	20	55	37	—	—	—	—	<i>S. frontalis</i>
78	103	30	37	20	57	40	65	55	73	—	<i>C. leucophaea</i>
79	106	38	—	—	—	—	—	—	—	—	<i>D. maculatus</i>
82	107	39	39	20	60	41	62	58	64	—	<i>A. stuartii</i>
78	101	38	40	20	60	39	—	58	66	—	<i>A. swainsonii</i>
74	93	31	38	19	57	40	51	54	54	111	<i>R. fuscipes</i>

42. *Neotrombicula derricki* (Womersley)

Trombicula derricki Womersley, 1954, *Trans. R. Soc. S. Aust.*, 77 : 67.

Material. Three paratypes and several other specimens with the same data.

Notes. This species is distinct from other Australian species of *Neotrombicula* with one mastitibiala and two mastitarsalae on leg III (the other five are also listed in this paper) in showing two genualae I (both internal and external distal rather than internal distal alone), a long outstanding seta on telofemur III, and strongly branched sensillae.

43. *Neotrombicula gemini* Domrow

Neotrombicula gemini Domrow, 1971, *J. Aust. ent. Soc.*, 10 : 112.

Material. Twenty-nine larvae, *Rattus fuscipes*, Heathmere, Vic., 21-24.vii.1968, J.H.S.; three larvae, *R. fuscipes*, Forrest, Vic., 2.x.1967, J.H.S. and R.T.

Notes. These specimens confirm the original record. Variation from DS commencing 2.8.8 is minimal; in 40 specimens, four showed 2.8.7, four 2.9.8 and one 2.8.9.

44. *Neotrombicula novaehollandiae* (Hirst)

Trombicula novaehollandiae Hirst, 1929, *Proc. Zool. Soc. Lond.*, 1929 : 172.

Material. Two syntypes.

One larva attached near cloaca, *Sericornis frontalis*, Mount Keira, N.S.W., 24.ix.1967, H.B.

Eleven red larvae around eyes and mystacial vibrissae, and in ears, *Macropus rufogriseus*, Maydena, Tas., 15.ix.1961, B.C.M. Four larvae, *Macropus parma*, Doyle's River State Forest, 45 miles north-west of Wauchope, N.S.W., viii.1973, G.M.M. Twenty-four red larvae attached as for *M. rufogriseus*, *Thylogate billardierii*, Maydena, Tas., 4.ix.1951, B.C.M. Nine larvae attached behind scrotum, *Potorus tridactylus*, Cobargo, N.S.W., 8.ix.1968, A.L.D.

Eight larvae, *Trichosurus vulpecula*, North Midlands, Tas., 2.vii.1962, R.H.G.

Five larvae, *Dasyurus maculatus*, Bessieville, Vic., 29.vii.1964, R.J.; nine larvae, *D. maculatus*, Piper's River, Tas., 10.vi.1973, B.L.M. Eleven larvae, *Dasyurus vicerrinus*, Deddington, Tas., 27.vii.1972, R.H.G. Thirty-three larvae, *Antechinus flavipes*, Mount Robinson, S.A., 29.vi.1970, R.A. Six larvae, *Antechinus stuartii*, near Melbourne, Vic., 29.viii.1972, R.S. Thirteen larvae, *Antechinus swainsonii*, near Gembrook, Vic., 13.iii.1967, D.S.S.; nine larvae, *A. swainsonii*, Sherbrooke Forest, Dandenong Ranges, Vic., 4.vii.1966, R.M.W.

Thirty-five larvae, *Rattus fuscipes*, Mount Robinson, S.A., vi.1970, R.A.; 32 larvae, *R. fuscipes*, Mount Magnificent, S.A., 20.vii.1970, R.A.; two larvae, *R. fuscipes*, Heathmere, Vic., 21.vii.1968, J.H.S.; 24 larvae, *R. fuscipes*, Forrest, Vic., 1-2.x.1967, J.H.S. and R.T.; 31 larvae, *R. fuscipes*, Cordeaux Dam, N.S.W., 10.vii.1966, C.E.C. Two larvae, *Rattus lutreolus*, Forrest, Vic., 2.x.1967, J.H.S. and R.T.

Notes. This material is doubly valuable: the localities cover much of south-eastern Australia (including Tasmania), and the specimens from South Australia are virtually topotypes. The scutal standard data (average values) decrease towards the north, but clearly only one species is involved.

Scutal standard data in micra of N. novaehollandiae

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	DS	Locality
74	95	29	37	26	62	34	57	53	76	101	73	South Australia
71	95	29	36	26	62	34	57	54	68	106	64	Tasmania
71	94	30	38	24	62	34	57	57	74	109	70	Victoria
74	99	31	39	24	63	37	63	52	75	112	74	Cobargo
69	88	26	33	24	57	31	43	46	55	95	54	Cordeaux Dam
68	87	27	33	23	56	31	44	46	55	97	57	Doyle's River

The specimens from Gembrook, while showing a certain delicacy of structure and scutal measurements rather smaller than other Victorian specimens, are also assigned here.

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	DS
66	86	27	34	22	56	38	45	46	50	—	58
72	88	28	35	21	56	40	46	43	56	101	57
67	86	26	35	22	57	37	50	43	58	—	58
72	87	26	34	23	57	37	53	—	58	98	62
66	86	25	32	20	52	34	53	45	61	—	61
69	88	27	35	22	57	37	45	45	53	95	53
69	87	26	34	22	56	37	49	44	56	98	58

45. *Neotrombicula thylogale* (Womersley)

Trombicula thylogale Womersley, 1954, *Trans. R. Soc. S. Aust.*, 77: 71.

Material. Three paratypes and several other specimens with the same data.

Notes. Scutal measurements of this material indicate that the shallowness of the shield (AP 25) figured by Womersley is real, and the species is therefore maintained.

Scutal standard data in micra of N. thylogale

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	DS
64	80	26	32	21	53	25	—	—	—	—	50
66	82	28	31	25	56	25	32	40	43	—	46
67	85	30	31	25	56	25	36	—	46	95	48
64	81	27	30	22	52	25	35	—	49	—	50
67	84	28	30	22	52	25	34	41	50	—	46
65	81	27	30	22	52	25	35	40	48	90	51
66	82	28	31	23	54	25	34	40	47	92	48

Genus SISECA Audy

46. *Siseca rara* (Walch)

Trombicula rara Walch, 1924, *Trans. V bienn. Congr. fur east. Assoc. trop.*

Med. (Singapore, 1923), 593.

Material. Two larvae attached in axillae, *Lygosoma tenuis*, Colcarra Creek, near Yeppoon, Qd, 31.viii.1965, H.A.S. ; 14 parchment-coloured larvae attached in axillae, *L. tenuis*, Manifold Station, near Rockhampton, Qd, 4.ix.1965, H.A.S.

Notes. This species has not previously been recorded from Australia, but the scutal measurements of the above specimens agree with Womersley's (1952) larger values for material from the Philippines and New Guinea (it should be noted that this author's material from Malaya and Queensland has since been described as two distinct species, *S. subrara* Audy and *S. southcotti* Womersley and Audy, see Domrow, 1962a).

Scutal standard data in micra of S. rara

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens
86	102	62	17	45	62	36	25	23	36	—
92	110	64	19	52	71	36	—	24	38	—
86	103	61	19	45	64	32	—	—	—	61
87	105	61	19	46	65	35	—	20	34	—
79	97	55	20	44	64	39	24	20	32	58
85	102	58	20	47	67	33	27	22	34	—
85	103	59	21	48	69	35	27	22	36	—
86	103	60	19	47	66	35	26	22	35	60

47. *Siseca vandiemeni* Domrow

Siseca vandiemeni Domrow, 1962, *J. ent. Soc. Qd.*, 1: 23.

Material. Twenty-six larvae, *Lygosoma ocellatum*, North Scotdale, Tas., 21.i.1962, R.H.G.

Notes. This is a new host record (Domrow, 1962a).

Genus TROMBICULA Berlese

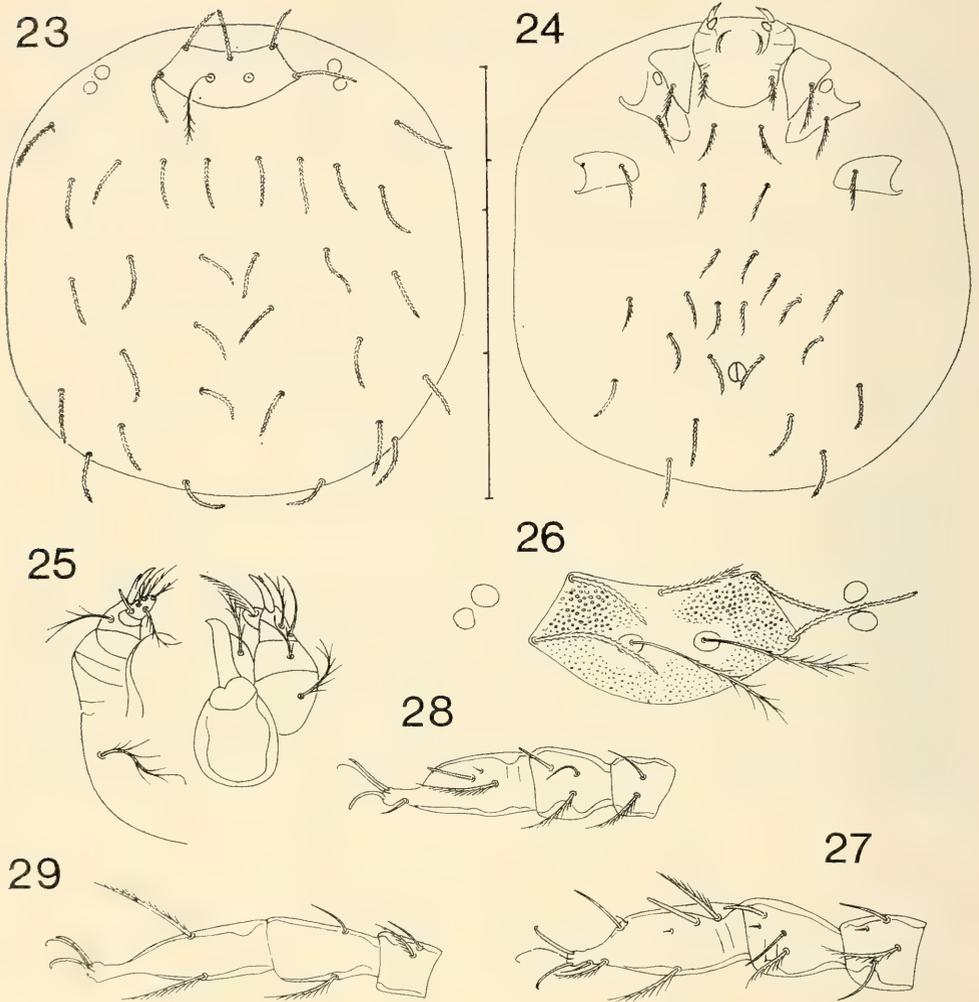
48. *Trombicula quadriensis* Womersley and Heaslip

(Figs 23-29)

Trombicula quadriense Womersley and Heaslip, 1943 (*sic*), *Trans. R. Soc. S. Aust.*, 67: 79.

Material. One paratype from Cairns, Qd.

Three larvae, *Trichosurus vulpecula*, D'Aguilar Range, Qd, 4.iv.1957, R.D.



Figs 23-29. *Trombicula quadriensis* larva. 23-24. Dorsal and ventral views of idiosoma (engorged). 25. Dorsal and ventral views of capitulum. 26. Scutum and eyes. 27-29. Specialized setation of legs I-III. (Each division on the scales = 100 μ .)

One larva, *Antechinus stuartii*, near Melbourne, Vic., 29.viii.1972, R.S.; seven larvae, *A. stuartii*, Powelltown, Vic., vii-viii.1973, I.B.

Notes. Previous records of this species as originally understood are all from North Queensland (Domrow, 1962*b*, 1967*b*). Standard scutal measurements are:

AW	PW	SB	ASB	PSB	SD	AP	AM	AL	PL	Sens	Locality
57	82	22	18	20	38	23	29	29	41	—	Palmerston
56	83	22	20	20	40	22	32	29	37	53	"
55	80	20	20	19	39	22	26	26	40	—	"
43	66	16	20	19	39	22	—	26	32	—	D'Aguilar
49	73	18	21	20	41	21	—	25	32	—	"
53	81	17	24	20	44	22	25	30	43	—	Melbourne
52	78	19	20	20	40	22	28	28	38	53	

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CORRIGENDA

Acarologia, 13: 557. In couplet 1 of key, amend setal formulae to read 1-3/2-0 and 1-3/1-0. *PROC. LINN. SOC. N.S.W.*, 88: 218. In line 6, read "eared" for "earless". *PROC. LINN. SOC. N.S.W.*, 93: 314. In line 6, read "textureless" for "textures".

THE RUGOSE CORAL GENERA *STREPTELASMA* HALL, *GREWINGKIA*
DYBOWSKI AND *CALOSTYLIS* LINDSTRÖM FROM THE LOWER
SILURIAN OF NEW SOUTH WALES

R. A. McLEAN*

(Plates I and II)

[Accepted for publication 12th December, 1973]

Synopsis

Streptelasma recisum sp. nov. is described from the Late Lower or Early Middle Llandoveryan Bridge Creek Limestone of the Four Mile Creek area, central New South Wales. *Grewingkia parva* sp. nov., *G. neumani* sp. nov. and *Calostylis panuarensis* sp. nov. are described from the Brown Mudstone Horizon near Angullong, central New South Wales, this unit being probably stratigraphically equivalent to the Bridge Creek Limestone. Possible affinities between the genera *Grewingkia* Dybowski and *Calostylis* Lindström are discussed.

INTRODUCTION

The rugose corals described occur in horizons of the Panuara Group southwest of Orange in central New South Wales. A summary of the stratigraphy of these horizons (Bridge Creek limestone at Four Mile Creek and Brown Mudstone Horizon at Angullong) together with evidence for their late Lower or early Middle Llandoveryan age are given by McLean (1974). Their distribution is illustrated in Text-fig. 1.

This paper presents the first description of the genera *Streptelasma* Hall, *Grewingkia* Dybowski and *Calostylis* Lindström from Australia. The species "*Streptelasma*" *australe* (Foerste, 1888) from the Upper Silurian of the Yass district, New South Wales, is not a representative of *Streptelasma* as that genus is currently defined (see discussion below).

SYSTEMATIC PALAEOLOGY

The morphological terminology used is that employed by Hill (1956) and Neuman (1969).

All numbers of specimens in the University of Sydney Palaeontological Collections bear the prefix SUP. Where more than one section has been prepared from the one specimen, the numbers bear the suffix *a*, *b*, etc.

Text-figures have been prepared from tracings of photographs.

Family STREPTELASMATIDAE Nicholson
in Nicholson and Lydekker, 1889

Diagnosis (based on Hill, 1956, p. F268). Solitary or fasciculate coralla generally with short minor septa and with septal stereozone often developed. Dissepiments lacking and tabulae usually domed, complete and incomplete.

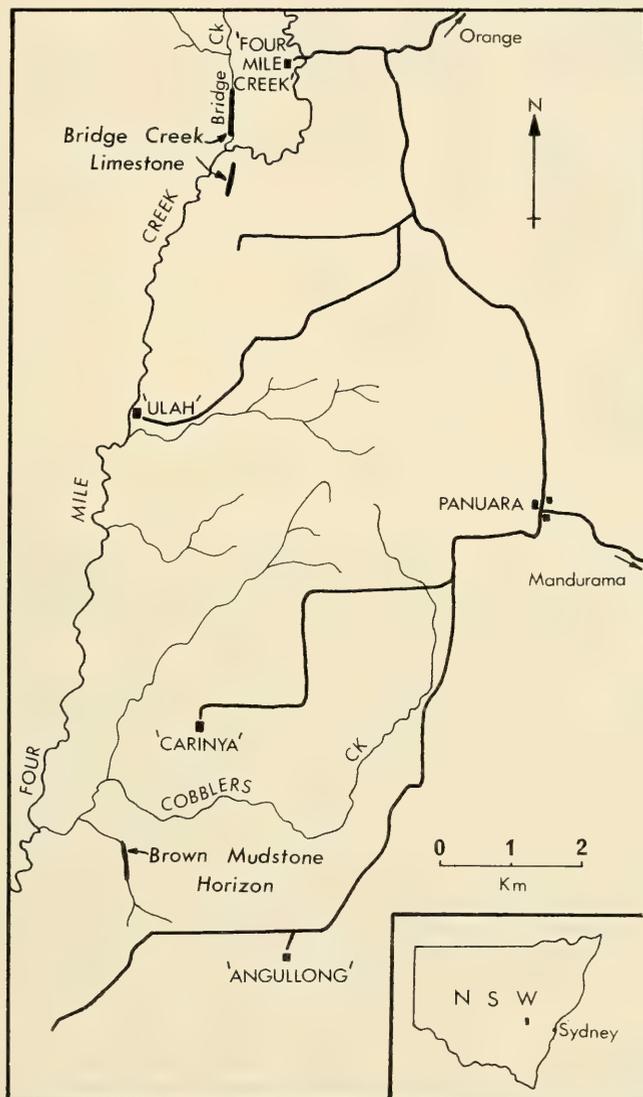
Subfamily STREPTELASMATINAE Nicholson
in Nicholson and Lydekker, 1889

Diagnosis. Septal stereozone may or may not be developed. Septa lamellar, complete throughout ontogeny.

Discussion. The generic composition of this subfamily is considered here as that given by Hill (1956, pp. F268–F269), although *Coelostylis* Lindström

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has been shown to possess monacanthine septa and has been transferred to the family Tryplasmataidae Etheridge (Neuman, 1967). Genera subsequently described and considered here as representatives of the Streptelasmatinae include *Porfirieviella* Ivanovskiy, 1963 ; *Helicelasma* Neuman, 1969 ; *Borelasma* Neuman,



Text-fig. 1. Distribution of the Bridge Creek Limestone and Brown Mudstone Horizon, South-east of Orange, New South Wales.

1969 ; *Crassilasma* Ivanovskiy, 1962 ; and *Kenophyllum* Dybowski, 1873. The relationships of these latter genera to the type genus *Streptelasma* Hall, 1847, are discussed below.

Genus *STREPTELASMA* Hall, 1847

- 1847 *Streptelasma* Hall, p. 69
 1873 *Calophyllum* Dybowski, p. 75
 1873 *Streptelasma*; Dybowski, p. 384
 ? 1901 *Zaphrentis*; Lambe, p. 118 (*non* Rafinesque and Clifford, 1820)
 ? 1901 *Zaphrentis*; Lambe, p. 119
 1927 *Dybowskia* Wedekind, p. 17
 ? 1928 *Zaphrentis*; (*part.*) Twenhofel, p. 114
 ? 1928 *Streptelasma*; Troedsson, p. 110
 1933 *Dybowskia*; Scheffen, p. 7
 1937 *Streptelasma*; (*part.*) Cox, p. 2
 1940 *Brachyelasma* Lang, Smith and Thomas, p. 28
 1955 *Brachyelasma*; Nikolaeva, p. 22
 1956 *Brachyelasma*; Kaljo, p. 71
 1958 *Brachyelasma*; Kaljo, p. 102
 1958 *Brachyelasma*; Reiman, p. 36
 ? 1960 *Brachyelasma*; Pestana, p. 868
 1963 *Brachyelasma*; Ivanovskiy, p. 42
 ? 1965a *Brachyelasma*; Ivanovskiy, p. 104
 1969 *Streptelasma*; Neuman, p. 8
 1971 *Streptelasma*; Scrutton, p. 207
 ? 1971 *Brachyelasma*; Lavrusevich, p. 51
non 1970 *Streptelasma*; Flügel and Saleh, p. 287

Type species. *S. corniculum* Hall, 1847, Trenton Limestone, New York (? Middle Caradocian).

Diagnosis (based on Neuman, 1969, p. 8). Solitary streptelasmatic coral with cylindrical, ceratoid or trochoid corallum with a convex cardinal side. Major septa in brephic and neanic stages long, thin or moderately dilated, normally fused into a weak axial structure. Major septa in ephebic stage thin, comparatively short, normally not forming axial structure. Tabulae of complete, convex type, often provided with complementary plates.

Discussion. Until recently, knowledge of the internal structure of the genus *Streptelasma* Hall, 1847 (type species *S. corniculum*), had been based on Canadian material described by Lambe (1901). Subsequent workers have used these descriptions as a basis for ascribing other specimens to the genus. Lambe's material is characterized by early growth stages having thickened major septa extending to the corallite axis. However, Hall's original type material had never been studied in thin section until the work of Neuman (1969), who found that the internal structure showed thin septa extending to the axis in the early stages, and that later the thin major septa became withdrawn from the axis. It thus became necessary to redefine *Streptelasma* as it was understood at that stage, and since the genus *Brachyelasma* Lang, Smith and Thomas, 1940, shows the same septal arrangement as Hall's syntypes of *S. corniculum* revealed on sectioning, *Brachyelasma* was included by Neuman as a junior subjective synonym of *Streptelasma*.

Neuman (1969) proposed the new genus *Helicelasma* (type species *H. simplex* Neuman, 1969) for forms included in *Streptelasma* under its old interpretation. Species now ascribed to the genus *Streptelasma* are generally those interpreted by earlier authors as belonging to *Brachyelasma*. Included in the family Streptelasmaticidae are a number of genera that are obviously very closely related to *Streptelasma*. Distinctions between these genera can normally only be made by study of the character of their early ontogenetic stages. Such studies have generally been done only by recent workers (e.g. Kaljo, 1956, 1958; Reiman, 1958; Ivanovskiy, 1963; and Neuman, 1969). Hence, of the many streptelasmaticid species described in the past, only a relatively small proportion may be

ascribed to a particular streptelasmatic genus with certainty. The genera showing closest similarities to *Streptelasma* are listed in Table 1, together with their distinguishing features.

TABLE 1
Distinguishing Features of Streptelasma and Related Genera

Genus	Neanic Stage	Ephebic Stage
<i>Streptelasma</i> Hall, 1847 ..	Septa show little dilation; axial structure may be present	Major septa, thin, withdrawn from axis
<i>Porfirieviella</i> Ivanovskiy, 1963	As in <i>Streptelasma</i>	Major septa thin, reaching axis and may form weak axial structure
<i>Dinophyllum</i> Lindström, 1882	Septa moderately dilated	Septa may show moderate dilation, reach axis and typically form vortex
<i>Helicelasma</i> Neuman, 1969	Septa strongly dilated, usually in contact; no axial structure	As in <i>Porfirieviella</i>
<i>Borelasma</i> Neuman, 1969 ..	As in <i>Helicelasma</i>	As in <i>Streptelasma</i>
<i>Crassilasma</i> Ivanovskiy, 1962	As in <i>Helicelasma</i>	Septa strongly dilated, reaching or almost reaching axis
<i>Kenophyllum</i> Dybowski, 1873	Septal structure is apparently similar to that of <i>Crassilasma</i> but tabulae are absent at all stages.	

The relationships of *Streptelasma*, *Porfirieviella* and *Dinophyllum* are uncertain. As mentioned above, *Streptelasma* typically shows septa withdrawn from the axis in the ephebic stage. However, in some species, the septa are only slightly withdrawn (e.g. *S. estonicum* Dybowski as described by Kaljo, 1958, and Neuman, 1969). Hence such forms are not widely different from those having septa extending to the axis as in *Porfirieviella*, e.g. *P. stokesi* (Edwards and Haime) as described by Ivanovskiy (1963). The major features distinguishing *Dinophyllum* from *Porfirieviella* appear to be formation in *Dinophyllum* of an axial vortex by the major septa and the presence of weak dilation of the septa. Ivanovskiy (1970a, p. 121) has in fact suggested that *Porfirieviella* differs only from *Dinophyllum* in lacking an axial vortex and that the genera should be considered synonymous. This feature is again demonstrated to be gradational in *Streptelasma* by Neuman (1969), the formation of an axial vortex being limited of course by the fact that the septa do not reach the axis in that genus. However, twisting of the axial ends of the major septa is exhibited by some species of *Streptelasma*, e.g. *S. primum* Wedekind and *S. linnarssoni* (Lindström) as described by Neuman (1969). The early ontogenetic stages of *Dinophyllum* (as in *D. involutum* Lindström, described by Minato, 1961) show long major septa, weakly dilated and similar to some species of *Streptelasma* (e.g. *S. corniculum* Hall; see Neuman, 1969). Future study of a larger variety of material may reveal that differences between these two genera and *Streptelasma* are merely gradational, in which case they should all be considered synonymous.

In a restudy of the composition of the genus *Streptelasma*, it is evident that many species, although similar to *Streptelasma* in their ephebic stage, are not well enough known in their earlier growth levels to be classified in that genus with certainty.

Brachyelasma fervida Kaljo, 1958, from the Oandu Horizon (Caradocian) of Estonia, possesses long, thin major septa in both ephebic and ? neanic stages

(Kaljo, 1958, Pl. I, figs 5, 6) but in the ephebic stage some septa reach the axis and there appears to be a weak axial structure of septal lobes and lamellae rather reminiscent of the genus *Grewingkia* Dybowski. Kaljo (1958, p. 104) also stated that major septa reach the axis. Ivanovskiy (1965*b*) listed *B. fervida* as a species of *Porfirieviella*, but Neuman (1969) included it in his revised genus *Streptelasma* (no mention was made by Neuman of *Porfirieviella*). The incomplete nature of Kaljo's material makes it difficult to classify the species with certainty. Similarly, *B. oanduensis* Kaljo, 1956, from the Keyla Horizon (Caradocian) of Estonia has long, thin major septa in the ? ephebic stage (Kaljo, 1956, Pl. I, fig. 10), but was included in his revised *Streptelasma* by Neuman (1969). It too was included in *Porfirieviella* by Ivanovskiy (1965*b*) but lacks sufficient illustration of its growth stages for definite classification. Ivanovskiy (1963) described the new Siberian Platform species *Brachyelasma siluriense* and *B. fossulatum* from the Upper Llandoveryan, and *B. nikiforovae* from the Upper Caradocian. While all possess short, thin major septa in the ephebic stage, no figures were given of the earlier stages and their inclusion in *Streptelasma* cannot be certain. Ivanovskiy (1970*b*) later included all three species in the Upper Llandoveryan *B. sibiricum* Nikolaeva from the Siberian Platform, but the synonymy of *B. siluriense* at least appears doubtful. More material, particularly of the younger stages, is necessary before a definite classification of these forms is possible. Similarly, *Brachyelasma concavifundatum* Ivanovskiy, 1965*a*, from the Upper Llandoveryan of the Siberian Platform, lacks illustration of its early growth stages. However, it has thin, short major septa in the ephebic stage. Ivanovskiy (1970*b*) listed it as a sub-species of *B. sibiricum*.

Two new species of *Brachyelasma* were described from Tadzhikistan by Lavrusevich (1971). *B. agbaschiricum* from Horizon A (Upper Ordovician) has not been studied in its early growth stages. It has strongly dilated, short major septa in the ephebic stage, however, and may be a representative of *Streptelasma*, although the septa are thicker than is typical of that genus. *B. digitiforme* from Horizon H (Upper Llandoveryan) also has been described only from ephebic sections, but these appear typical of *Streptelasma*, and the species when fully studied should probably be included in that genus.

Although no North American representatives of *Streptelasma*, as now defined, have been described (except the type species), several species show some similarities to that genus. *Zaphrentis affinis* Billings, 1865 (Lambe, p. 118, Pl. VII, fig. 6) from the Ellis Bay Formation (? Lower Llandoveryan) of Anticosti Island shows thin major septa withdrawn from the axis in the ? ephebic stage, but earlier ontogenetic stages have not been described. Also *Zaphrentis patens* Billings, 1865, from the Jupiter Formation (Upper Llandoveryan) of Anticosti Island (Lambe, 1901, p. 119, Pl. VIII, fig. 2) has thin, short major septa at the calice, but early ontogenetic stages are unknown. *Zaphrentis anticostiensis* Twenhofel, 1928, from the Gun River-Jupiter Formations (Middle-Upper Llandoveryan) of Anticosti Island has thin, major septa somewhat withdrawn from the axis at the calice but extending to the axis below this level (Twenhofel, 1928, p. 114, Pl. I, figs 6-8). Unfortunately no sections of early growth stages have been figured, but it is likely that the species belongs to *Streptelasma*. *Brachyelasma bassleri* Pestana, 1960, from the Johnson Spring Formation (? Trenton) of California has thin major and minor septa strongly withdrawn from the axis in ephebic sections, but the early ontogenetic stages are not described and the species cannot be assigned to *Streptelasma* with certainty.

Two species from the ? Llandoveryan of Iran recently described by Flügel and Saleh (1970), *Streptelasma ruttneri* and *S. shirgeshtensis*, have sufficiently well-described early growth stages to permit classification. *S. ruttneri* has long, thin, major septa extending to the axis in ephebic sections, while the septa are strongly dilated and also reach the axis in the neanic stage. It is probably a

representative of *Helicelasma* Neuman, 1969. *S. shirgeshtensis* on the other hand has short, thin septa in the ephebic stage, while in the neanic stage they are long and moderately dilated. This species should probably be included in the genus *Borelasma* Neuman, 1969.

The only form from Australia previously described as belonging to *Streptelasma* is "*S.*" *australe* (Foerste, 1888), represented in the "Phacops bed" of the Yass district, New South Wales (Hill, 1940, p. 410). Link and Druce (1972, p. 7) listed "*Streptelasma*" *australe* from the Rainbow Hill Marl Member (Link, 1970) at Yass, apparently the horizon referred to by Hill. The age of this unit is regarded as late Ludlovian (Link, 1970; Link and Druce, 1972). From the descriptions of Hill (1940) it is apparent that "*S.*" *australe* possesses dilated septa in its early ontogenetic stages, together with some development of an axial structure. Hence it is not a representative of *Streptelasma* as defined by Neuman and its systematic position needs to be resolved.

Range. Middle Caradocian of Estonia, New York, ? California; Upper Caradocian of Estonia, ? Siberian Platform; Ashgillian of Sweden, Norway, Estonia, Urals, ? Tadzhikistan, ? Anticosti Island, Greenland; Lower Llandoveryan of Estonia, Venezuela and N.S.W.; Upper Llandoveryan of the Siberian Platform, ? Tadzhikistan, ? Kazakhstan, ? north-east U.S.S.R., ? Anticosti Island.

Streptelasma recisum sp. nov.

Plate I, figs 1-6

Derivation of name. Latin *recisus* = reduced, referring to the nature of the septa in the ephebic stage.

Material. Holotype SUP 45167. Paratypes SUP 45168-45175. Preserved in a colony of the tabulate coral, *Priscosolenia* sp., Bridge Creek Limestone. Late Lower or Early Middle Llandoveryan.

Diagnosis. Small *Streptelasma* with average calice diameter 8-10 mm. Septa in neanic stage thin, short (reaching up to 0.5 corallite radius) and few in number (average 26-30). Minor septa very weakly developed; stereozone absent. Tabulae horizontal or sagging axially.

Description. Corallum trochoid-ceratoid, weakly curved. Specimens incomplete but dimensions are of the order of at least 25 mm in height and maximum observed diameter of approximately 15 mm. Average corallite diameter 8-10 mm towards base of calice. Epitheca thin and peripheral stereozone lacking at all stages of growth.

In neanic stage (Plate I, figs 3, 6) septa are thin and extend almost to corallite axis. No axial structure formed but a few septal lamellae may be present in axial region. ? Cardinal septum shorter than other septa in neanic stage (Plate I, fig. 6), but owing to poorer preservation this cannot be confirmed in later growth levels. In neanic stage, at diameters of 5 mm and 7.5 mm, septa number 24 and ? 25 respectively (SUP 45172, 45171). In the ephebic stage, septa are withdrawn from axis, with a common length of about 0.5 of radius of corallite (Plate I, figs 1, 5). In ephebic sections available, at corallite diameters of 7.5-9.5 mm, septa number 26-30. Minor septa are difficult to distinguish and if present occur only as very fine ridges on corallite wall. High in calice, septa are reduced greatly in length (approximately 0.2 total corallite radius).

Tabulae mainly complete, moderately downflexed peripherally, horizontal or sagging axially, particularly in late stages of growth. Average spacing of tabulae 0.4-0.6 mm in small specimen (SUP 45175) and 0.5-1.2 mm in large form (SUP 45174). Complementary plates lacking.

Remarks. An interesting feature in regard to the growth form of *S. recisum* sp. nov. is its relationship to the massive tabulate coral *Priscosolenia* in which the described material grew commensally. Small flexures in the rugosan

epitheca are common, indicating mutual adjustment of both corals during growth. Invaginations of the epitheca of *S. recisum* into the *Priscosolenia* colony are evident, possibly for support of the rugosan form (Plate I, fig. 3, particularly). The corallites of the *Priscosolenia* colony have also been considerably disturbed and distorted by the presence of the *Streptelasma* (Plate I, fig. 4).

The only described species of *Streptelasma* to show any strong similarities to *S. recisum* sp. nov. is *S. sibiricum* (Nikolaeva, 1955) from the Upper Llandoveryan of the Siberian Platform. It resembles the New South Wales form in having comparable corallite dimensions, thin septa almost reaching the axis in the neanic stage and major septa of similar number (up to 35) and length (up to 0.5 of corallite radius) in the ephebic stage. It is also similar in having the minor septa lacking or very short in the ephebic stage, tabulae of similar shape and little or no peripheral stereozone. However, a clear distinction between the two forms may be made, since *S. sibiricum* has rather more dilated, thin, wedge-shaped septa in the ephebic stage and possesses a very prominent cardinal fossula with very short cardinal septum in the late neanic or early ephebic stage (Ivanovskiy, 1963, Pl. IX, fig. 1B). No definite fossula has been observed in any of the Bridge Creek material. There is evidence of very short minor septa in the material of Nikolaeva (1955, Pl. XLVIII, fig. 2a).

The form described by Twenhofel (1928) as *Zaphrentis anticostiensis* from the ? Middle-Upper Llandoveryan of Anticosti Island shows quite strong similarities to *S. recisum*, but lacks illustration and detail of the early ontogenetic stages and so cannot be closely compared with it. Similarities include septal number (23 at corallite diameter of 8 mm), the minor septa reduced to "spines or nodes", very thin major septa in the ephebic stage extending half or more than half-way to the axis, and the shape of the tabulae. Twenhofel stated (p. 114) that the major septa reach the axis below the level of the calice. A cardinal fossula with a short cardinal septum on the calice floor is also reported, although this is not illustrated by Twenhofel.

Genus GREWINGKIA Dybowski, 1873

- 1873 *Grewingkia* Dybowski, p. 384
- 1901 *Streptelasma*; Lambe, p. 109 (*non* Hall, 1847)
- 1927 *Kiaerophyllum* Wedekind, p. 17
- 1933 *Kiaerophyllum*; Scheffen, p. 16
- 1937 *Streptelasma*; (*part.*) Cox, p. 10
- 1948 *Streptelasma* (*Kiaerophyllum*); Wang, p. 102
- 1950 *Streptelasma* (*Kiaerophyllum*); Wang, p. 213
- 1956 *Grewingkia*; Hill, p. F268
- 1956 *Grewingkia*; Duncan, Pl. 21, figs 4a, b
- 1958 *Grewingkia*; Reiman, p. 34
- 1958 *Streptelasma* (*Kiaerophyllum*); Kaljo, p. 25
- 1960 *Brachyelasma*; Tcherepnina, p. 387 (*non* Lang, Smith and Thomas, 1940)
- 1960 *Grewingkia*; Pestana, p. 868
- 1961 *Streptelasma* (*Grewingkia*); Kaljo, p. 62
- 1961 *Rectigrewingkia* Kaljo, p. 62
- 1961 *Cyatholasma* Ivanovskiy, p. 120
- 1963 *Grewingkia*; Nelson, p. 33
- 1965a *Cyatholasma*; Ivanovskiy, p. 76
- 1965a *Grewingkia*; Ivanovskiy, p. 77
- 1965 *Grewingkia*; Kaljo and Klaaman, p. 420
- 1969 *Grewingkia*; Neuman, p. 33
- 1970a *Grewingkia*; Ivanovskiy, p. 121
- 1970 *Grewingkia*; Flügel and Saleh, p. 291
- 1971 *Grewingkia*; Lavrusevich, p. 49

Type species. *Clisiophyllum buceros* Eichwald, 1856, Upper Ordovician, Estonia. (Type horizon unknown.)

Diagnosis (abbreviated from Neuman, 1969, p. 33). Solitary streptelasmatid coral with cylindrical, ceratoid or trochoid corallum. Septa moderately or heavily dilated early in ontogeny, major septa long, forming narrow axial structure. Later in ontogeny major septa relatively short and thin, axial structure broad, composed of numerous irregularly intertwined septal lobes and lamellae. Calicular boss present or absent. Tabulae few or numerous, complete or incomplete, with or without complementary plates.

Discussion. The genus *Grewingkia* has been interpreted in many different ways by previous workers. Representatives described as belonging to *Kiaerophyllum* (Wedekind, 1927; Scheffen, 1933) were considered as being a subgenus of *Streptelasma* Hall by Wang (1948). Hill (1956), however, recognized the synonymy of *Kiaerophyllum* and *Grewingkia* and considered the latter to be distinct from *Streptelasma*. Kaljo (1958) applied the classification adopted by Wang but later (1961) recognized the synonymy suggested by Hill. He still, however, considered *Grewingkia* to be a subgenus of *Streptelasma*. Kaljo (1961) also erected a new genus, *Rectigrewingkia* (see discussion below), to include the species *G. anthelion* Dybowski and *G. lutkevitchi* Reiman (possibly with *G. eminens* Eichwald and *G. formosa* Dybowski, both needing revision). Neuman (1969) in a thorough revision of *Grewingkia* considered differences between the two genera to be gradational and restored *Rectigrewingkia* to the genus *Grewingkia*. Furthermore, Neuman revived the classification of Hill (1956) and gave *Grewingkia* the status of a full genus. This classification has been adopted by the author of this paper.

Densigrewingkia Neuman, 1969, and *Lobocorallium* Nelson, 1963, are similar to *Grewingkia* in possessing a reticulate axial structure. *Densigrewingkia* may be distinguished by its concave cardinal side and the considerable amounts of sclerenchyme in its axial structure, particularly in the early ontogenetic stages. *Lobocorallium* differs in having a prominent cardinal fossula and a tri-lobed corallum with the lobes corresponding to the cardinal and alar septa. As mentioned above, *Rectigrewingkia* Kaljo, 1961, is considered by Neuman (1969), and in this paper, to be a synonym of *Grewingkia*. The major distinguishing feature of *Rectigrewingkia*, according to Kaljo, is the presence of rounded septal lamellae in the axial structure, as compared with intertwined lobes and lamellae in species of *Grewingkia*. This appears to be only a gradational feature and is not considered important enough for formation of a separate genus. Further detail on the distinction of these genera may be obtained in Neuman (1969).

The genera *Bighornia* Duncan, *Bodophyllum* Neuman, *Dalmanophyllum* Lang and Smith and *Ditoecholasma* Simpson apparently all possess a solid axial structure of fused septal lobes and lamellae, together with complete, lamellar septa peripherally. Further study of these forms is required; they may possibly be synonymous (Ivanovskiy, 1965a; and Neuman, 1969). Their solid axial structure serves to distinguish them from *Grewingkia* in any case.

The species *G. dentiseptata* Lavrusevich, 1971, from Horizon B of the Zeravshan-Gissar region of Tadzhikistan was considered as Lower Llandoveryan by Lavrusevich (1971). However, Horizon B is correlated with the Porkuni Horizon of Estonia (Lavrusevich and Menakova, 1971), and the latter is generally considered as Upper Ashgillian (Männil, 1966; Rõõmusoks, 1970). Ivanovskiy (1965b) also considered the fauna of Horizon B to be more typical of the Upper Ordovician. *G. dentiseptata* shows no close similarities to the New South Wales representatives of the genus.

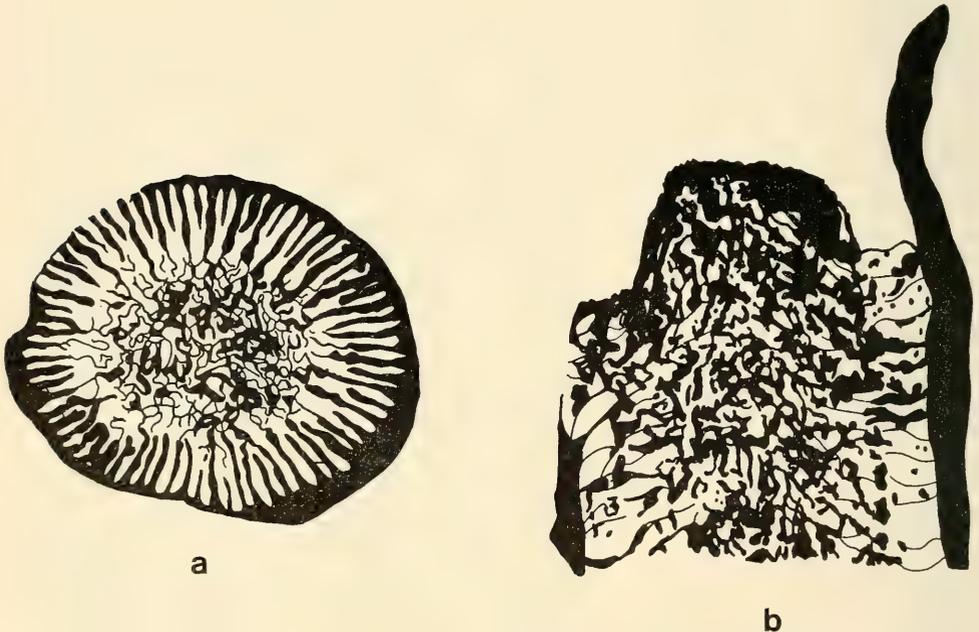
Range. Lower Caradocian of ? Scotland ; ? Middle Caradocian of California ; Upper Caradocian of Estonia, south-west Siberia, Manitoba ; Ashgillian of Ireland, Norway, Sweden, Estonia, Tadzhikistan, Quebec, Michigan ; Llando-verian of north-east Iran ; Lower or Middle Llando-verian of New South Wales.

Grewingkia parva sp. nov.

Plate I, figs 7-10 ; Text-fig. 2a, b

Derivation of name. Latin *parvus* = small.

Material. Holotype SUP 45151. Paratypes SUP 45152-45155, 63274. Brown Mudstone Horizon, Angullong district. Late Lower or Early Middle Llando-verian.



Text-fig. 2. *Grewingkia parva* sp. nov. a. SUP 45151a, holotype, transverse section, $\times 4$. b. SUP 45152, paratype, longitudinal section, $\times 4$.

Diagnosis. Small, subcylindrical *Grewingkia* with a prominent calicular boss and narrow peripheral stereozone. Corallite diameter up to 14 mm and maximum septal number ranges from 60 to 70. Minor septa long, up to half length of major septa, the latter typically showing dilated lobes at their axial extremities. Axial structure compact, approximately half corallite diameter. Tabulae mainly incomplete, weakly concave peripherally and strongly arched through axial zone.

Description. Subcylindrical corallum gradually tapering proximally although proximal end not preserved in any specimens. Epitheca thin, although all specimens have most of epitheca lacking. Average corallite diameter 11-14 mm with a height of at least 30 mm. Calice rather shallow with steep sides comprising stereozone and epitheca only (Plate I, fig. 9). Depth of calice 8 mm in preserved corallite height of 23 mm (total height probably at least 30-35 mm) in only specimen showing this feature (SUP 45152). Calicular boss

prominent, with a height of 3 mm and diameter approximately 6 mm (SUP 45152). Calice floor flat around axial boss.

Peripheral stereozone narrow, with a width of 1–1.5 mm in ephebic sections, consisting of dilated septa and indeterminate ? sclerenchyme tissue. Septa of two orders, thin, with average number 64–70 (possibly 78 in SUP 45154), typically showing small, rounded projections irregularly developed on sides of septa. Major septa also show larger dilated lobes at their axial extremities. Minor septa extend well beyond peripheral stereozone, reaching a length of approximately half that of major septa. Axial structure has mainly consistent diameter throughout visible ontogeny (approximately the distal 23 mm) and is about half the diameter of corallite. Structure composed of tightly anastomosing septal lobes and lamellae, generally of smaller diameter than septa themselves.

Tabulae mainly complete with generally constant spacing of about 0.7 mm. Individual tabulae strongly arched in axial reticulate zone, conforming in shape with profile of calicular boss. In peripheral area tabulae are weakly sagging and may be faintly traced curving distally in peripheral stereozone. Complementary plates may be present in peripheral regions.

Remarks. Owing to lack of sufficient well-preserved material, the early ontogenetic stages of this species could not be studied. However, enough material was available to allow some comparisons with other representatives of the genus. None of the described species of *Grewingkia* are closely similar to *G. parva* sp. nov. However, some relationships with *G. anguinea* (Scheffen, 1933) from Division 5A (Lower Ashgillian) of Norway as described by Neuman (1969) may be seen in its corallite size, septal number and development of long minor septa, narrow stereozone, weak dilation of septa, convex tabulae with slightly concave peripheral portions and an axial structure of comparable dimensions. It clearly does not have the ceratoid growth form of *G. anguinea*, although this growth form only appears obvious in the more proximal regions, which have not been found preserved in any of the Angullong specimens. *G. anguinea* also differs in having a deeper calice with far less steeply inclined walls, a low, broad calicular boss, as a result of less convex tabulae, no broadly dilated septal lobes at the axial extremities of the major septa and a less dense axial complex of septal lobes and lamellae.

G. contexta Neuman, 1969, from the Boda Limestone (Ashgillian) of Sweden, also shows some similarities to the local form in having similar corallite dimensions, subcylindrical growth form (but ceratoid also), and a prominent calicular boss. Like *G. parva*, it also shows a narrow stereozone, generally long minor septa late in ontogeny and comparable size and appearance of the axial structure. However, it too may be clearly distinguished by showing a greater number of septa (90–100 average), lack of large lobes on the axial septal extremities and strong septal dilation in the cardinal quadrants until quite late in ontogeny, although it is possible those early stages have not been preserved in the Angullong specimens. Other differences include a less steep-walled calice, different shape of the tabulae (Neuman, 1969, p. 47, fig. 37J) and a fixing groove and rootlets on the convex side of the corallite.

The only other Llandoveryan species described (*G. alternata* Saleh in Flügel and Saleh, 1970, from the Niur Formation of Iran) differs from *G. parva* in having much larger size (corallite diameter 30 mm), proportionately fewer septa ($n/Dc=5$ for *G. parva* and 3.5 for *G. alternata*), less tightly anastomosing elements in the axial structure and a lack of lobes on the major septa.

The specimen sectioned at the base of the calice (SUP 45154, Plate I, fig. 10), while tentatively included in *G. parva*, shows a greater number of septa (78), longer minor septa and very pronounced dilated lobes on the axial extremities of the major septa.

Grewingkia neumani sp. nov.

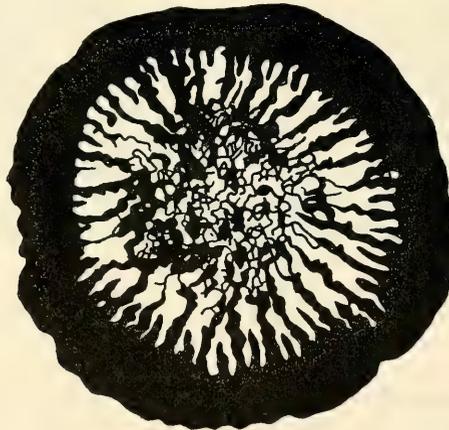
Plate I, figs 11, 12; Plate II, fig. 1; Text-fig. 3

Derivation of name. After Dr. B. Neuman, for his important studies of streptelasmatic corals.

Material. Holotype SUP 20115. Paratypes SUP 45156, 45157. Coarse calcarenite lens in Brown Mudstone Horizon, Angullong district. Late Lower or Early Middle Llandoveryan.

Diagnosis. Trochoid or ? subcylindrical *Grewingkia* characterized by very deep calice, wrinkled epitheca and very broad peripheral stereozone. Corallite diameter ranges up to at least 35 mm and septal number ranges up to 96 in subcylindrical forms. Minor septa short, major septa typically showing club-like dilated lobes at axial extremities. Axial structure 0.3–0.5 corallite diameter, septal lamellae and lobes coarse in trochoid forms, more tightly intertwined and finer in smaller representatives. Tabulae slightly sagging peripherally, weakly convex axially.

Description. Corallum trochoid in two specimens while the other shows subcylindrical growth form. Epitheca smooth with transverse wrinkles evident in SUP 45157. Calice very deep and in largest specimen (holotype SUP 20115, with height of at least 30 mm) calice has approximate depth of 15 mm. Corallite diameter varies from about 50 mm at top of calice to about 30 mm near calice base in largest specimen. Subcylindrical specimen reaches diameter of 14 mm. Calical boss low and wide.



Text-fig. 3. *Grewingkia neumani* sp. nov. SUP 45156a, paratype, transverse section, $\times 4$.

Broad peripheral stereozone of dilated septa and ? sclerenchyme. In largest specimen stereozone thins progressively from about 8 mm in width at base of calice to approximately 2 mm near its top. Maximum of about 60 septa in subcylindrical form, ranging to 94–96 in large trochoid specimen. Septa dilated so as to be in contact in stereozone where trabecular structure of septa is shown. Trabeculae, although poorly preserved, exhibit coarse fibres radiating obliquely from central axis (Plate II, fig. 1). Beyond stereozone major septa thin markedly to about 0.3 of their peripheral width and internal structure is obscured by recrystallization. Small “nodes” and undulations are evident on septa in this region in transverse section (Text-fig. 3). Minor septa barely extend beyond peripheral stereozone, while in subcylindrical form they extend approximately 0.3 of the distance between stereozone and axial structure. Width of axial structure ranges from 0.3 to 0.5 corallite diameter and it is composed of loosely

intertwined septal lamellae and lobes. In subcylindrical form septal elements in axial structure are finer and more tightly reticulate. Tabulae sagging adjacent to peripheral stereozone, weakly arched in axial region. Tabular spacing approximately 1 mm.

Remarks. The only described species of *Grewingkia* to show any strong similarities to *G. neumani* is the Upper Caradocian *G. altaica* (Tcherepnina, 1960) from the Altai and Salair areas of south-west Siberia. Features in common include similar corallite dimensions and growth form (for the large, trochoid representatives), coarse, intertwined septal lamellae of the axial structure, and a broad stereozone consisting mainly of dilated septa. In particular, the transverse section illustrated by Ivanovskiy (1961, Pl. XV; 1965a, Pl. XXVI, fig. 3) appears closely comparable. However, differences may be seen in the rather more irregular and wavy nature of the major septa in the region between the stereozone and axial structure of *G. altaica* although this is not as apparent in the Altai material of Tcherepnina (1960, Pl. O-X, fig. 3b). Also in *G. altaica* the tabulae are more strongly downflexed near the periphery and there is no development of club-shaped dilated lobes on the axial ends of the major septa such as is found in *G. neumani*.

The smaller, subcylindrical specimen assigned to *G. neumani*, while differing in possessing longer minor septa, rather wavy major septa and a more densely compacted axial structure, is included in the species because of its similarly constructed broad stereozone. If further material is found that confirms there is a sharp distinction between these two types, then it may be advisable to consider the latter form perhaps as a new species or as a subspecies of *G. neumani*. For the present, however, they are grouped together.

G. neumani may be distinguished from *G. parva* sp. nov. primarily by the broad peripheral stereozone, shorter minor septa and deeper calice of the former. A feature in common, however, is the development of the dilated axial lobes on the major septa. This characteristic is apparently unique to the local representatives of *Grewingkia*. However, some Silurian species of the genus *Calostylis* show this feature, Smith (1930a, p. 261) recording that "individual strands of this peripheral and axial tissue . . . dilate so as to form numerous nodes, and the numerous free endings are nearly always swollen and rounded". Possible affinities between *Grewingkia* and *Calostylis* are discussed further below.

The most useful descriptions of the septal microstructure of *Grewingkia* have been those of Kato (1963), Ivanovskiy (1967) and Wang (1950). Kato (1963, Text-fig. 10. 3) illustrated fibres diverging obliquely from a central axis in a septum of "*Grewingkia* sp.". Ivanovskiy (1967, Fig. 3d) showed a similar structure in *G. altaica*. The septal microstructure of the New South Wales representatives of *Grewingkia* is very poorly preserved and only the holotype of *G. neumani* (SUP 20115) shows this feature in any detail. As can be seen from Plate II, fig. 1, a rather coarse system of fibres diverging from a central axis occurs in the dilated septa of the peripheral stereozone. Beyond the stereozone recrystallization has obscured the microstructure but a similar structure on a smaller scale would be expected, according to Kato and Ivanovskiy. The septal microstructure illustrated by Ivanovskiy (1967, Fig. 3d) for *G. altaica* is quite closely comparable to that of *G. neumani*.

Family CALOSTYLIDAE Roemer, 1883

Diagnosis (modified from Hill, 1956, p. F296). Solitary and colonial corals with major and minor septa perforate; axial ends of major septa lobed and reticulate, forming spongy axial structure. Tabulae generally distally arched in axial region; dissepiments lacking. Epitheca typically not developed over entire corallum.

Discussion. The family Calostylidae is taken here to include the genera *Calostylis* Lindström, *Palaeareaea* Lindström and *Helminthidium* Lindström, all characterized by possession of perforate septa. The taxonomic affinities of this group of corals, however, are open to question, as mentioned by Hill (1956), although they are generally recognized as being probably closest to the streptelasmatis.

Ivanovskiy (1961), in his discussion of the family Calostylidae, described a new genus, *Cyatholasma*, from the Upper Caradocian of the Salair region of south-west Siberia. *Cyatholasma* was characterized by complete, lamellar septa in the peripheral region of the corallite and a reticulate structure of septal lobes and lamellae at the axis. The synonymy of this form with *Grewingkia* Dybowski was recognized by Ivanovskiy (1967, 1970a). However, the genus *Calostylis* possesses perforate septa peripherally but an axial structure similar to that of "*Cyatholasma*". Ivanovskiy (1961) thus inferred that "*Cyatholasma*" represented a link between the Middle-Upper Ordovician Streptelasmatisidae which have complete, lamellar septa throughout, and the Upper Ordovician-Silurian Calostylidae which have perforate, incomplete septa. He subsequently (1965a, 1968) included *Grewingkia* in the family Calostylidae, although the genus has been generally placed in the Streptelasmatisidae by most workers (e.g. Dybowski, 1873; Hill, 1956; Neuman, 1969). As representatives of the Streptelasmatisidae (e.g. *Streptelasma* Hall, see above and Neuman, 1969) may often show traces of septal lobes and lamellae in the axial zone at some stage of their ontogeny, it seems preferable to include *Grewingkia* in that family. However, the evident close relations of *Calostylis* to *Grewingkia* would suggest that the calostylids are most probably an aberrant branch of the Streptelasmatisidae. It may in fact be best to consider *Grewingkia* and *Calostylis*, together with related forms, as representatives of a distinct subfamily of the Streptelasmatisidae, characterized by forms with well-developed axial reticulate structure. Further work on these and similar forms is required before a definitive statement on the systematic position of the calostylids is possible. Particularly important in this regard would be ontogenetic studies of the species of *Calostylis* and *Grewingkia*. Hence for the present the family Calostylidae is retained for *Calostylis* and other perforate genera.

Genus CALOSTYLIS Lindström, 1868

- 1865 ? *Clisiophyllum* Kjerulf, p. 22 (not seen)
- 1868 *Calostylis* Lindström, p. 421
- 1878 *Calostylis*; Nicholson and Etheridge, p. 65
- 1906 *Calostylis*; Foerste, p. 322
- 1912 *Calostylis*; Reed, p. 123
- 1917 *Calostylis*; Foerste, p. 200
- 1930a *Calostylis*; Smith, p. 257
- 1930b *Calostylis*; Smith, p. 294
- 1958 *Calostylis*; Kaljo and Reiman, p. 27
- 1961 *Calostylis*; Ivanovskiy, p. 119
- 1963 *Calostylis*; (? part.) Ivanovskiy, p. 92
- ? 1965 ? *Calostylis*; Stumm, p. 47
- 1966 *Calostylis*; Sytova and Ulitina, p. 243
- 1971 *Calostylis*; Lavrusevich, p. 69

Type species. *C. cribaria* Lindström, 1868 = ? *Clisiophyllum denticulatum* Kjerulf, 1865. Wenlockian, Gotland.

Diagnosis. Corallum solitary or often with lateral buds; having perforate septa which degenerate axially and peripherally into a reticulate structure. Tabulae complete and incomplete, distally arched; dissepiments absent. Epitheca may not be developed over entire corallum.

Discussion. A useful summary of previous work on the genus *Calostylis* has been given by Ivanovskiy (1961). He suggested a phylogenetic scheme whereby *Calostylis* was seen as a Lower Silurian intermediate between *Cyatholasma* (= *Grewingkia*), of Late Ordovician age, and the genus *Helminthidium* Lindström, a Middle-Upper Silurian form. *Helminthidium* differs from *Calostylis* in that the septa are completely broken down to a retiform condition and individual radial septa cannot be distinguished. The other member of the family Calostylidae, the early Silurian *Palaeoraea* Lindström, is an astreoid form having perforate septa and "spongy" axial structure. Ivanovskiy (1961) suggested that *Palaeoraea* was derived from "*Cyatholasma*" but it could equally have been derived from *Calostylis*.

The species composition of *Calostylis* is badly in need of revision. *C. tomesi* Smith, 1930, from the Wenlock Limestone (Upper Wenlockian) of Shropshire, *C. parvula* Foerste, 1917, from the "Laurel Limestone" (Wenlockian) of Ohio and *C. dravidiana* Reed, 1912, from the ? Llandoveryan of Spiti, Central Himalayas, require detailed thin-section study before their affinities are known. The type species, *C. denticulata* (Kjerulf, 1865), is a very variable form, and there are several species which are very similar to it, and may in fact be found to be synonymous when they are studied in more detail. Among these forms are *C. togata* Smith, 1930, from the Purple Shales (Upper Llandoveryan) of Shropshire, and *C. spongiosa* Foerste, 1906, from the Waco Limestone (Upper Llandoveryan) of Kentucky, both of which were stated to be closely similar to *C. denticulata* by Smith (1930a). *C. concavifundatus* Reiman in Kaljo and Reiman, 1958, from the Porkuni Horizon (Upper Ashgillian) of Estonia and Llandoveryan of the Siberian Platform is also similar to the type species and was listed as a synonym of it by Ivanovskiy (1970b).

C. aberrans Smith, 1930, from the Pentamerus Beds and Purple Shales (Upper Llandoveryan) of Shropshire, is closely similar to *C. roemeri* Smith, 1930, differing only in its distorted growth form. There are intermediate forms between it and *C. roemeri* (Smith, 1930a, 1930b) and it may be better considered as synonymous with or a subspecies of *C. roemeri*.

The phaceloid Middle Devonian species from Kentucky, *C. ? trigemma* (Davis, 1887), as described by Stumm (1965) differs from the typical Ordovician-Silurian representatives of the genus in its growth habit and very weakly developed axial structure. Its systematic position is uncertain.

Range. Upper Ashgillian of Estonia; Lower-Middle Llandoveryan of Estonia, Siberian Platform, Tadzhikistan, New South Wales; Upper Llandoveryan of England, Scotland, Norway, Gotland, Estonia, Urals, Tadzhikistan, ? Central Himalayas, Kentucky; Wenlockian of England, Gotland, Tadzhikistan, Ohio; ? Ludlovian of Kazakhstan.

Calostylis panuarensis sp. nov.

Plate II, figs 2-10; Text-fig. 4a, b

Derivation of name. After the major stream in the area, Panuara Rivulet, an alternative name for Four Mile Creek.

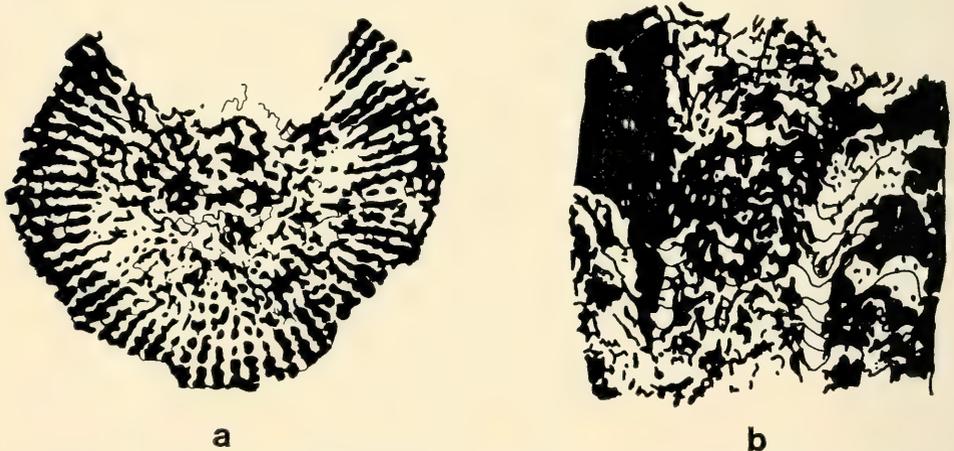
Material. Holotype SUP 69220. Paratypes SUP 45158-45166, 63275, 69221. Brown Mudstone Horizon, Angullong district. Late Lower or Early Middle Llandoveryan.

Diagnosis. *Calostylis* either solitary or with rare lateral buds, cylindrical, with average corallite diameter of 12 mm. Broad axial and narrow peripheral reticulate zone; 66-76 strongly perforate septa. Tabulae sagging, with axial convex zone. Abundant sclerenchyme filling of corallite interior.

Description. Corallum solitary, in three cases (SUP 45163, 45165, 63275) showing budding. Increase is lateral and non-parricidal. Corallites cylindrical, slightly tapering proximally with sharp increase in diameter soon after budding takes place (Plate II, fig. 2). Epitheca not preserved in any specimens. Corallite diameter varies from 10·5 to 15·5 mm in material available, with an average of 12–13 mm. Weak calicular boss present but complete calice not preserved in any specimen. Disposition of layering of sclerenchyme in corallites suggests rather shallow calice.

Septa entirely perforate, 66–76 in number, breaking down axially and to a lesser extent peripherally, into anastomosing, reticulate structure. Minor septa long, extending 0·5–0·7 of length of major septa, as best illustrated by holotype SUP 69220 (Plate II, figs 8, 9; Text-fig. 4*a*). Individual septa not traceable axially beyond margin of central reticulate structure, which varies from about 4·5 to 5 mm in diameter, i.e. slightly more than 0·3 of corallite diameter. Peripheral reticulate zone, where it can be clearly differentiated, reaches diameter of about 1·5 mm, averaging 0·1 of diameter of corallite.

Tabulae generally not clearly defined, strongly sagging near margin of axial structure and prominently convex in the axial zone, although difficult to trace actual plates in this area. Tabulae may be defined by abundant sclerenchyme deposits and layers of sediment, suggestive of periodic pauses in growth (e.g. SUP 45166). Average spacing of tabulae of about 0·7–1 mm.



Text-fig. 4. *Calostylis panuarensis* sp. nov. a. SUP 69220b, holotype, transverse section, $\times 4$. b. SUP 45158b, paratype, longitudinal section, $\times 4$.

Remarks. Of the described species of *Calostylis*, four show some similarities to *C. panuarensis*. Of these, the type species, *C. denticulata* (Kjerulf, 1865) from the Llandoveryan-Wenlockian of Scandinavia and Central Asia has perhaps the closest affinities. From the descriptions by Smith (1930*a*) of material from Gotland and Norway, similarities may be seen in the cylindrical, solitary growth form together with lateral, non-parricidal increase in some specimens, long minor septa, almost extending to the axial zone, the size and nature of axial reticulate structure and the shape and disposition of the tabulae. The transverse section illustrated by Smith (1930*a*, Pl. XI, fig. 5) in particular appears very similar to the local form. However, the general size of corallites (common diameter 20 mm, reaching 35 mm in some cases, although some may be as small as 13 mm), the usually more clearly defined and wider peripheral reticulate zone, together

with a greater number of septa (average about 90, compared to 66–76 in *C. panuarensis*) serve to distinguish it from the Angullong species. According to Lindström (1868), *C. denticulata* may even have up to 140 septa.

C. denticulata has also been described from Horizon D (Lower Llandoveryan) to Horizon K (Lower Wenlockian) of the Zeravshan-Gissar region of Tadzhikistan (Lavrusevich, 1971). The form from this area differs slightly in showing a greater tendency of budding, larger size with proportionally greater number of septa, generally thinner septal elements and a wide peripheral reticulate zone. It is evident that the two species are very closely related.

Several of the inadequately studied species of *Calostylis* show similarities to *C. panuarensis* also. *C. togata* Smith (1930a), from the Purple Shales of Shropshire, is comparable to *C. panuarensis* in the features of growth form, septal size and axial structure and is also of more comparable dimensions (average corallite diameter 13 mm). However, it too differs in having a larger number of septa (approximately 90) and a considerably broader peripheral reticulate zone. As Smith (1930a, 1930b) pointed out and was discussed above, it is quite likely that *C. togata* may represent a smaller variant of *C. denticulata*.

The two described North American species also show similarities to *C. panuarensis*. *C. spongiosa* Foerste, 1906, from the Waco Limestone (Upper Llandoveryan) of Kentucky is comparable in growth form, size and axial structure but has a greater number of septa (100), weakly developed minor septa and a wide, thickened peripheral zone.

C. parvula Foerste, from the Laurel Limestone (Wenlockian) of Ohio is of comparable size, septal number and axial structure, but is more trochoid in growth form, has more clearly differentiated minor septa and the peripheral zone is not as clearly developed. However, this species has apparently not been studied in thin section and hence the internal structures are imperfectly known.

Therefore, while the local form is assigned here to a new species, further study of some of the European and North American representatives of *Calostylis* may lead to a revision of its taxonomic position. Particularly important in this respect would be a restudy of the smaller variants of *C. denticulata*.

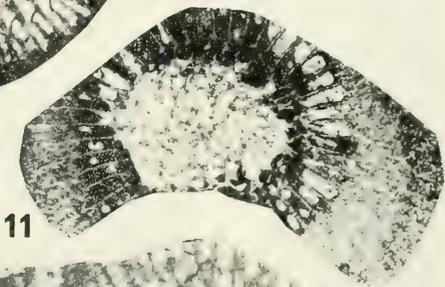
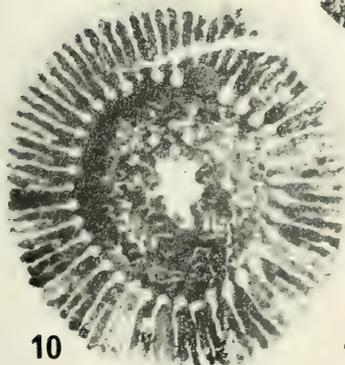
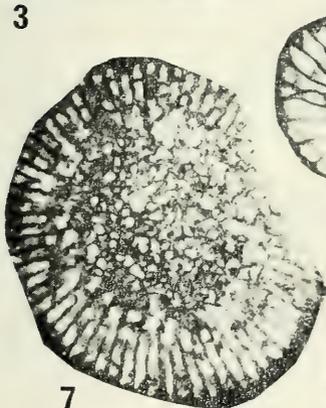
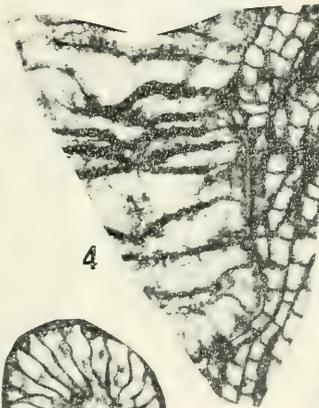
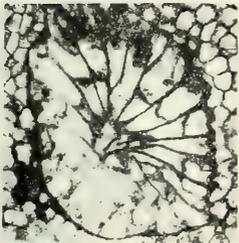
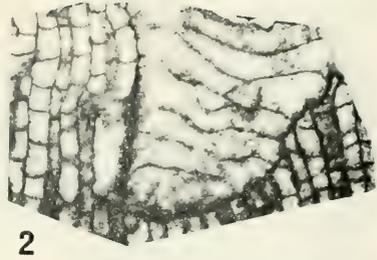
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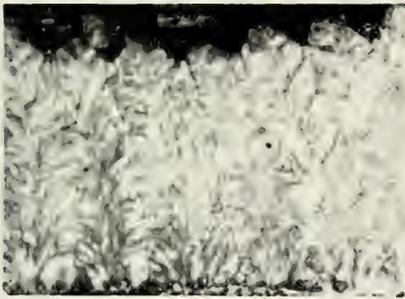
The author is grateful to Dr. B. D. Webby for critical comments on the manuscript. The work was partly supported by a Commonwealth Post-graduate Fellowship at the University of Sydney.

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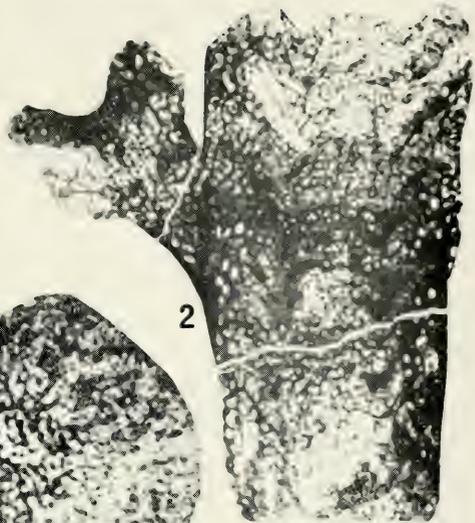
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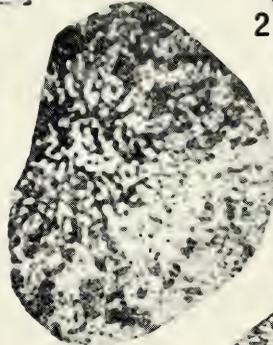
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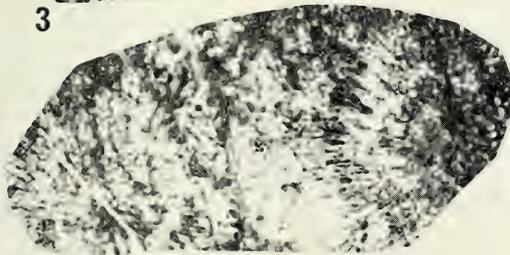
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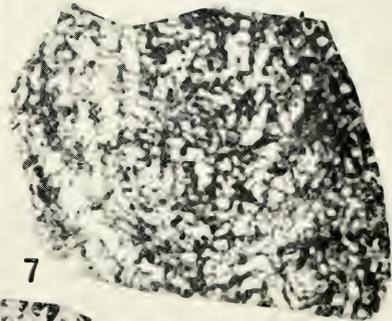
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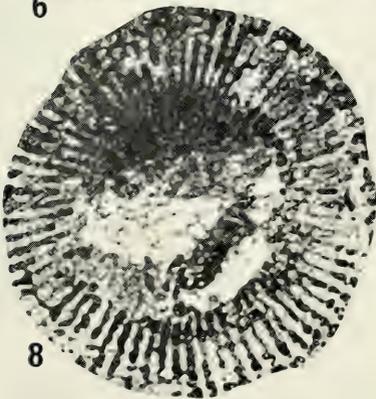
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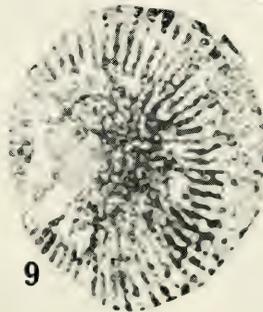
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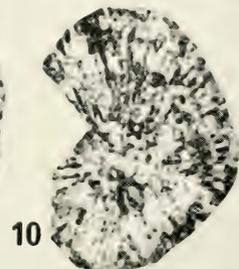
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EXPLANATION OF PLATES

PLATE I

Figs 1–6. *Streptelasma recisum* sp. nov., Bridge Creek Limestone, Bridge Creek, $\times 4$. 1. SUP 45167 (at left of figure), holotype, transverse section, ephebic stage ; SUP 45168 (at right), paratype, transverse section, ephebic stage. 2. SUP 45175, paratype, longitudinal section. 3. SUP 45171, paratype, transverse section, neanic stage. 4. SUP 45174, paratype, longitudinal section. 5. SUP 45169, transverse section, ephebic stage. 6. SUP 45172, paratype, transverse section, neanic stage.

Figs 7–10. *Grewingkia parva* sp. nov., Brown Mudstone Horizon, Angullong, $\times 4$. 7. SUP 45151a, holotype, transverse section. 8. SUP 45153, paratype, transverse section. 9. SUP 45152, paratype, longitudinal section. 10. SUP 45154, paratype, transverse section.

Figs 11–12. *Grewingkia neumani* sp. nov., coarse calcarenite lens, Brown Mudstone Horizon, Angullong. 11. SUP 20115a, holotype, transverse section, $\times 2$. 12. SUP 20115c, holotype, longitudinal section, $\times 4$.

PLATE II

Fig. 1. *Grewingkia neumani* sp. nov., coarse calcarenite lens, Brown Mudstone Horizon, Angullong. SUP 20115b, holotype, transverse section of peripheral region of corallite in calice, showing poorly preserved trabeculae, $\times 8$.

Figs 2–10. *Calostylis panuarensis* sp. nov., Brown Mudstone Horizon, Angullong. 2. SUP 45165, paratype, longitudinal section showing lateral bud, $\times 3$. 3. SUP 45158b, paratype, longitudinal section, $\times 4$. 4. SUP 45162a, paratype, transverse section, $\times 4$. 5. SUP 45161a, paratype, transverse section, $\times 4$. 6. SUP 45163a, paratype, transverse section showing lateral bud at left, $\times 4$. 7. SUP 45162b, paratype, longitudinal section, $\times 4$. 8. SUP 69220a, holotype, transverse section at level of calice, $\times 4$. 9. SUP 69220c, holotype, transverse section, $\times 4$. 10. SUP 45158a, paratype, transverse section, $\times 4$.

A LABYRINTHODONT TRACKWAY FROM THE MID-TRIASSIC NEAR SYDNEY, NEW SOUTH WALES

JULIAN PEPPERELL* AND GORDON GRIGG*

[Accepted for publication 24th October, 1973]

Synopsis

A recently discovered trackway of a large Mid-Triassic Labyrinthodont is described. Notable features of the trackway are the length (22 sequential imprints) and that the digits are laterally directed, suggesting a primitive stance.

INTRODUCTION

In July 1970, workmen digging a sewerage tunnel at Macquarie Fields, New South Wales, discovered what appeared to be footprints on the tunnel roof. The authors visited the site and ascertained 22 definite imprints constituting an excellent trackway made by a large Middle Triassic quadruped, probably a labyrinthodont amphibian. Because of its length and some unusual features, the trackway is of particular interest and warrants description.

METHOD OF STUDY

As the roof of the tunnel was soon to be concreted over, an accurate photographic record was made. The roof was divided into sections with chalk-marks and each section numbered. A series of photographs was then taken with oblique illumination to emphasize the relief of the individual footprints. A scale was included in each photograph. A photo-montage was then built up to represent the whole trackway and each imprint given a number. From this montage, a drawing was produced (Fig. 1). Scale measurements were made from a tracing of the montage and these dimensions are displayed in Table 1.

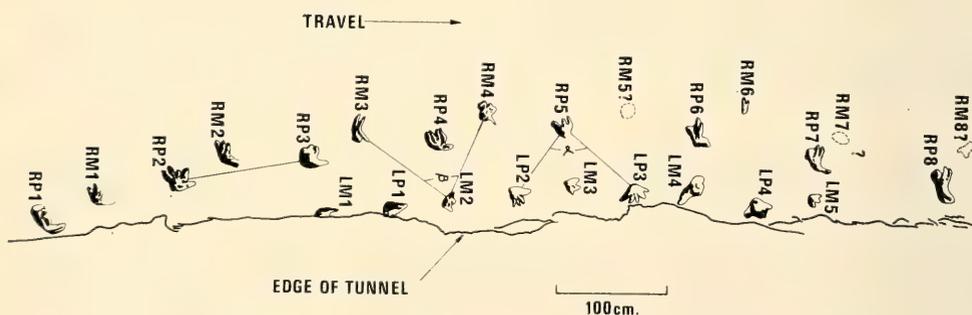


Fig.1. Scale diagram of the Labyrinthodont trackway.

DESCRIPTION

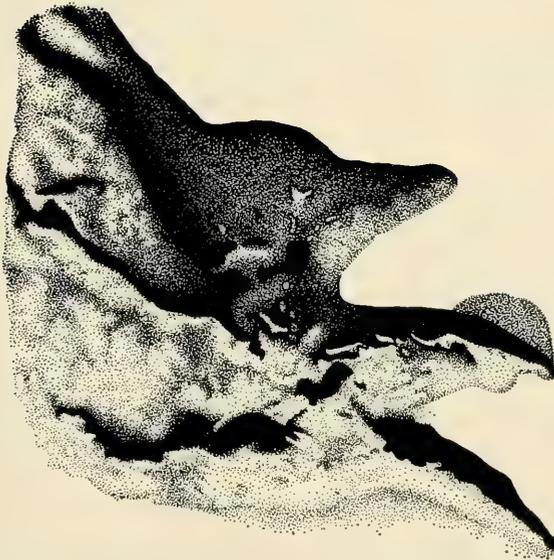
The trackway was in the Ashfield shales at the base of the Wianamatta Group, of Mid-Triassic age. It consisted of a series of casts of prints made in the underlying shale which had been removed during excavation of the tunnel. The trackway emerged from the unexcavated section of the roof and was exposed for three full strides before disappearing again (Fig. 1). The visible trackway consisted of casts as follows : eight right pes, eight right manus (three indistinct),

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10 cm

(a)



10 cm

Fig. 2. (a) Right manus ^(b)(RM 2). (b) Left pes (LP 2).

TABLE 1
*Dimensions of Trackway**
 (Length measurements in centimetres)

	Mean	Range	
Stride {	Right manus	117	113-122
	Left manus	111	106-114
	Right pes	115	111-119
	Left pes	112	109-114
	(Mean stride)	114)	
Trackway width	80		
Manus pace	94	84-101	
Pes pace	74	63-81	
Manus pace angulation	77°	73°-85°	
Pes pace angulation	99°	94°-107°	
Gleno-acetabular length	106		

* The reference point for measurements of length was taken as the base of the second outermost digit of both manus and pes.

four left pes, and five left manus. There were no signs of tail or body drag marks. Of particular interest is the lateral direction of the digits of both pes and manus from the axis of travel.

Dimensions that could be ascertained are given in Table 1. Gleno-acetabular length was determined by geometry to be 106 centimetres.

Prints RM2 and LP2 were the best preserved of manus and pes respectively. These are illustrated in Fig. 2. The manus appears to have three digits, the pes four. Most impressions have a ridge extending anteriorly which probably indicates a drag mark made during protraction of the limb. Unfortunately, these marks could have obscured an extra digit if it were present. The drag marks are more pronounced in those imprints made by right pes and right manus, probably because the animal was making a slow left turn. Webbing between digits is not indicated in either pes or manus, except for a slight suggestion of a membrane between the third and fourth digits in LP2, LP3, LP4, RP6, RP7 and RPS.

DISCUSSION

Because of the pace angulation and the angle of the digits, and because the only tetrapods known from this formation are amphibians, the trackmaker was probably a large Labyrinthodont. If so, then the gleno-acetabular length of 106 centimetres is consistent with a total length of about three metres. The laterally directed digits of pes and manus indicate a primitive stance close to that proposed by Morton (1926) as the likely stance for primitive tetrapods. Only one other trackway has been described with this primitive feature, an upper Devonian record from Victoria, Australia (Warren and Wakefield, 1972). Absence of marks indicating body or tail drag suggests either that the animal may have been wading through a shallow billabong or marsh with body weight partly supported by water or that the animal was capable of walking with its body clear of the ground.

ACKNOWLEDGEMENTS

We are grateful to personnel from the Metropolitan Water, Sewerage and Drainage Board for drawing our attention to their discovery. Advice and help from Dr. Anne Warren is gratefully acknowledged. Mr. David Stanley prepared the diagrams.

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A NEW TROGLOBITIC QUADRANNULATE LAND-LEECH FROM
PAPUA (HIRUDINOIDEA : HAEMADIPSIDAE s.l.)

LAURENCE R. RICHARDSON*

[Accepted for publication 24th October, 1973]

Synopsis

A troglobitic quadrannulate land-leech, *Leiobdella jawarereensis* gen. et sp. nov., is associated with insectivorous bats in the aphotic zone of a cave. Its general somital annulation corresponds with that of *Philaemon*, but differs in having the recurrent limb of the female median region about half the length of the procurvent limb, the lambertian organs posterior, elongate cylindrical, the organ much longer than its duct, and the first pair of nephropores lateral on viii a₁.

A 4-annulate land-leech from the aphotic zone of a cave near Jawarere, Papua, lacks general cutaneous pigment. The retinal cells of the eyes are pigmented; otherwise the preserved animal is opaque white. The animal is the same in life. Although many species of land-leeches are found in the vestibule of many caves, this is the first record of a troglobitic land-leech.

It is also the first record of a troglobitic leech among the euthylaematous leeches, which are characterized by a pharynx whose internal muscular ridges extend along its full length as dorsomedian and ventrolateral ridges, and by the fact both that somite v is the first complete somite and that it forms the lateral and ventral margins of the anterior sucker.

Euthylaematous leeches form a very large and diverse assembly. It contains the majority of leeches with a pharynx and includes not only freshwater, amphibious, terrestrial and terricolous jawed and jawless macrophagous leeches which ingest smaller animals entire, but also freshwater, terrestrial and terricolous jawed sanguivorous leeches.

The only previous record of a troglobitic leech is the aquatic, eyeless, opaque white *Dina absoloni* Johansson, 1913, found in some caves in Europe; but there is now knowledge of a similar leech in a cave in Japan. *D. absoloni* belongs to the smaller compact group having a strepsilaematous pharynx: the internal muscular ridges as a dorsomedian and ventrolaterals anterior to somite vii, transposing posterior to this to be dorsolaterals and a ventromedian for the length of the pharynx; with iv as the first complete somite forming the lateral and ventral margins of the pharynx. All leeches in this group are freshwater and macrophagous.

Considering the great diversity of habit and habitat of the euthylaematous leeches, it is of interest that the first record of a troglobitic species is not that of a macrophagous leech with its capacity to feed on the lesser fauna within a cave but of a terrestrial jawed sanguivore so restricted in habit as to be dependent on a vertebrate.

The 4-annulate land-leeches of the Australian Region are known to me in specimens from Tasmania, southern Victoria, eastern New South Wales, eastern Queensland, the Northern Territory, Papua and Lord Howe Island. They are a complex group which I have not yet been able to bring into satisfactory zoological order as a whole. Some few are distinctive in external meristic morphology, in the form of the auricle and in pattern.

* 4 Bacon St., Grafton, New South Wales, 2460.

The majority are monotonous in external meristic morphology, in the morphology of the alimentary tract and in the morphology of the reproductive systems, but they separate by pattern into groups, in the same manner as our aquatic jawed sanguivores. When the latter are grouped by pattern, genera can be separated within each group by distinctive differences in the morphology of the median regions of the reproductive systems. This is not possible in the 4-annulates since the median regions have been monotonous in form in those previously studied. This seemed to leave only pattern as a primary guide to genera.

In the absence of pattern, I was initially reluctant to base a new genus on the Jawarere leech. It seemed preferable to describe it as a new species and to assign the species to the genus *Philaemon*, based on *P. pungens* of Victoria (the traditional genus to which 4-annulate leeches are assigned), leaving the nature of the new genus until such time as a patterned species could be described as the type species. However, I now realize that both the form of the female median region in the Jawarere leech and the form of the lambertian organs are different from those of all other 4-annulates known to me. The combination of these with other features described below fully warrants the provision of a new genus.

A particular feature is the location of the first pair of nephropores in the marginal field, lateral on viii a₁ in the Jawarere leech (and also in a second species of 4-annulate from Papua still to be detailed and named).

Earlier (1969) I drew attention to fig. 8 in Blanchard (1917) which shows in a diagrammatic manner the dorsal aspect of the anterior somites of *Philaemon minutus* Blanchard 1917 of Samoa. In this figure, a pair of nephropores, labelled the second pair, is shown on viii a₁. I suggested there had been a simple error, or alternatively that these were in fact the first pair of nephropores. The latter now seems to be the case.

Lambert (1898) fully establishes the first pair of nephropores as labial in position in *P. pungens*, i.e. sited on the margin of the sucker at the level of vi a₁ (posterior to the position in my experience). They are labial and at iii/iv in *P. grandis* Ingram 1957 of Tasmania, and at about this level in other Australian 4-annulates I have studied, including *Neoterrabdella australis* Richardson, 1969. The first pair of nephropores is not recorded as other than labial in two-jawed and three-jawed 4-, 5- and 6-annulates elsewhere, and known to me only as labial in the 4-, 5- and 6-annulates in eastern Australia which are all two-jawed, with one exception.

The exception was the two-jawed 5-annulate *Idiobdella seychellensis* Harding, 1913, in the Seychelle Islands, a leech with other morphological characteristics which cause this genus to be separated from terrestrial jawed sanguivores elsewhere.

To date I have dissected specimens of 10 or 11 species of land-leeches in the Australian Region. I have published (1969) an account of *Neoterrabdella australis*, and there is more recently (Richardson, 1974) an account of *Domanibdella tristriata* (Goddard, 1909). To this knowledge can be added Lambert's description (1898) of *Philaemon pungens* and Ingram's descriptions (1957) of *P. pungens* and *P. grandis*. This is not a full fauna, but it is a usable sampling.

In all these, the ovaries are posterior in xii, or in the contiguous annuli of xii and xiii; the oviducts join at xii/xiii or anterior in xiii; the initial recurrent limb of the female median region is essentially equal in length to the length of the terminal procurvent limb, the latter slightly longer, about the length of an annulus or a little longer in those in which the female pore is median or slightly anterior in xii.

In the Jawarere leech, the ovaries and the junction of the oviducts are essentially at the same levels as in the others, but the initial recurrent limb of

the median region is short, about half or slightly less than half of the length of the terminal procurent limb. The difference is the same in a contracted as in an extended specimen.

Of the 4- and 5-annulate Australian land-leeches which I have dissected, only *Neoterrabdella australis* lacks lambertian organs.

In all the 5-annulates known to me, including *Chtonobdella limbata* Grube, 1866 (described by Lambert in 1899 under the name of "*Geobdella australiensis*") of central eastern New South Wales, "*Geobdella*" *whitmani* Lambert, 1899, of southern eastern Queensland, and *Domanibdella tristriata* of Papua, the lambertian organs are either posterior in position, situated in the contiguous halves of xxii and xxiii, the organ ovoid about the length of a somite, and the duct and organ nearly equal in length; or, as in *D. tristriata*, the organ longer, elongate cylindrical, from xxi/xxii to the middle of xxiii, the duct very short, its length no more than the width of the organ.

In the 4-annulates, the lambertian organs are anterior; in xx, the organ obtusely ovoid, short, and the duct long; or in the contiguous parts of xx and xxi, the organ longer, the duct shortened; but in both cases, the organ is much shorter than the duct, the length of the organ half or less than half of the length of the duct. The organs are in xx in *Philaemon pungens* (Lambert, 1899, pl. x, fig. 2).

In the Jawarere leech, the lambertian organs in xxi and xxii are elongate cylindrical, folded, the length of two somites, and the organ much longer than the duct, about twice its length, i.e. the lambertian organs and ducts differ from the form in the 4-annulates and resemble the form of these structures in the 5-annulates.

Only the general external meristic morphology is known for the great majority of land-leeches.

Phytobdella catenifera Moore, 1938, is a two-jawed 6-annulate land-leech from Johore, India. In his description of this species, Moore shows (1938, pl. v, figs 10, 11) the initial recurrent limb of the female median region as short, about half the length of the terminal procurent limb, and the lambertian organ as posterior in position, elongate, and more than twice the length of the short lambertian duct. Both therefore are the same as the Jawarere leech.

Keegan *et al.* (1969, fig. 39A) show the female median region in a two-jawed 6-annulate from Laos as having the two limbs equal in length.

Moore (1944) describes the lambertian organs as posterior, extending from xxi to the level of the end of the postcaecum, the duct short, the gland seven to nine times the length of the duct, in *Phytobdella lineata* Moore, 1944, and *Phytobdella maculosa* Moore, 1944, both of Papua. He does not adequately describe the female reproductive system. These are both two-jawed 6-annulates.

A two-jawed 6-annulate collected by Dr. Ewers at Mount Suckling, differs from the above species in details of the somital annulation. I find in this specimen that the two limbs of the female median region are essentially equal in length and that the lambertian organ is elongate cylindrical, folded on itself, extending anteriorly to xxi, the duct short, the gland six to seven times the length of the duct. Mount Suckling lies in Papua.

I review briefly elsewhere (Richardson, 1974) the manner in which land-leeches have been separated systematically. Initially, all 4-annulates were placed in the genus *Philaemon*, with the species separated on the location of the genital pores and the annulation of vii. Later, genera were separated on the number of jaws and on the presence or absence of lambertian organs.

To this I added (1969) the annulation of xxiv and xxv, the form of the auricle, and, recently, the annulation of vi, vii, etc., making a further step in the separation of genera.

The 4-annulate genera previously recognized in the Haemadipsidae (Soos, 1967) were *Philaemon*, a name proposed by Blanchard in 1897 for 4-annulates, but without detail until Lambert (1898); *Tritetrabdella* Moore, 1938; *Nesophilaemon* Nybelin, 1943. To these I added *Neoterrabdella* Richardson, 1969, and, from the nature of the reproductive systems, I removed *Nesophilaemon* from the Haemadipsidae.

Tritetrabdella of Penang, Malaya, has three jaws, lacks lambertian organs; xxiv, 2-annulate; genital pores, xi a_2/b_5 and xii $a_2 (a_2/b_5)$.

Neoterrabdella of the Northern Territory, Australia, lacks lambertian organs; xxiv, 3-annulate; xxv, 2-annulate; the auricles large, formed by the lateral ends of xxiv-xxvii; genital pores, xi $a_2 (a_2/b_5, b_5)$ and xii b_6 . *Philaemon*, of Victoria and Tasmania, Australia, as in Lambert (1898) and Ingram (1957), has lambertian organs; xxiv, uniannulate; auricles formed by the lateral ends of xxv-xxvii; genital pores, xi $b_5 (? b_5/b_6)$ and xii $b_6 (? b_5/b_6)$. Both genera have two jaws.

With genera separated as above, the Jawarere leech would be assigned to *Philaemon* as a species distinct in having the genital pores in xi b_6 and xii a_2/b_5 .

To the previous criteria for the separation of genera we can add the form both of the lambertian organ and of the female median region, and also the location of the first pair of nephropores. This combination excludes the Jawarere leech from the previously established genera.

If this is adopted, some generic separations can be anticipated in the 6-annulates, all currently in the genus *Phytobdella*.

Genus LEIOBDELLA gen. nov.

Derivation. *Leio*, smooth + *bdella*, leech.

Description. Somites viii-xxii, complete 4-annulate (total, 15); xxiii, incomplete 4-annulate; xxiv-xxvii, incomplete uniannulate; six annuli posterior to xxiii a_2 ; auricles lateral to xxv, xxvi, xxvii, margin lobate, incised; first nephropores lateral on viii a_1 ; duognathous; jaws housed in an annular groove; teeth, minute; salivary glands, sparse, no obvious columns of aggregated ducts; extrinsic radial musculature in vii-ix; pharynx thin-walled, internal muscular ridges represented by an undivided dorsomedian and a pair of ventrolateral ridges; pharynx terminates at viii/ix; crop compartmented, caecate, the compartments each with a pair of primary caeca at the median level and reduced secondary anterior and posterior caeca, excepting xix with secondary anterior caeca and postcaeca originating at the median level, extending in the paramedian chamber to xxiii/xiv and each continuing as a lambertian duct shorter than the elongate cylindrical lambertian organs in xxi and xxii; genital pores, xi $(b_5/b_6) b_6$ and xii a_2/b_5 ; male median region, amyomeric, micromorphic; female median region, myomeric, mesomorphic, haemadipsoid; testes, saccular; anterior region of the male paired duct reflecting in the median splanchnic chamber at xi/xii or in xii as a primary posteriorly directed loop, an epididymis on the initial portion of the recurrent limb, a sperm duct completing the recurrent limb and extending along the length of the procurrent limb; ejaculatory bulbs, present; ejaculatory ducts enter the anterior aspect of the basal portion of the minute atrium; ovaries, saccular, at xii/xiii or in xiii; oviducts join at xii/xiii to median in xiii; female median region, a posteriorly directed loop reflecting in xiii-xiii/xiv, the initial recurrent limb short, half or less of the length of the terminal procurrent limb; oviducal glandular sac expanded on the posterior aspect of the elbow of the loop.

Terrestrial. Sanguivorous. Australian Region, Papua.

Pattern. ? The type species, cavernicolous and lacking pattern.

Type species. *Leiobdella jawarereensis* sp. nov.

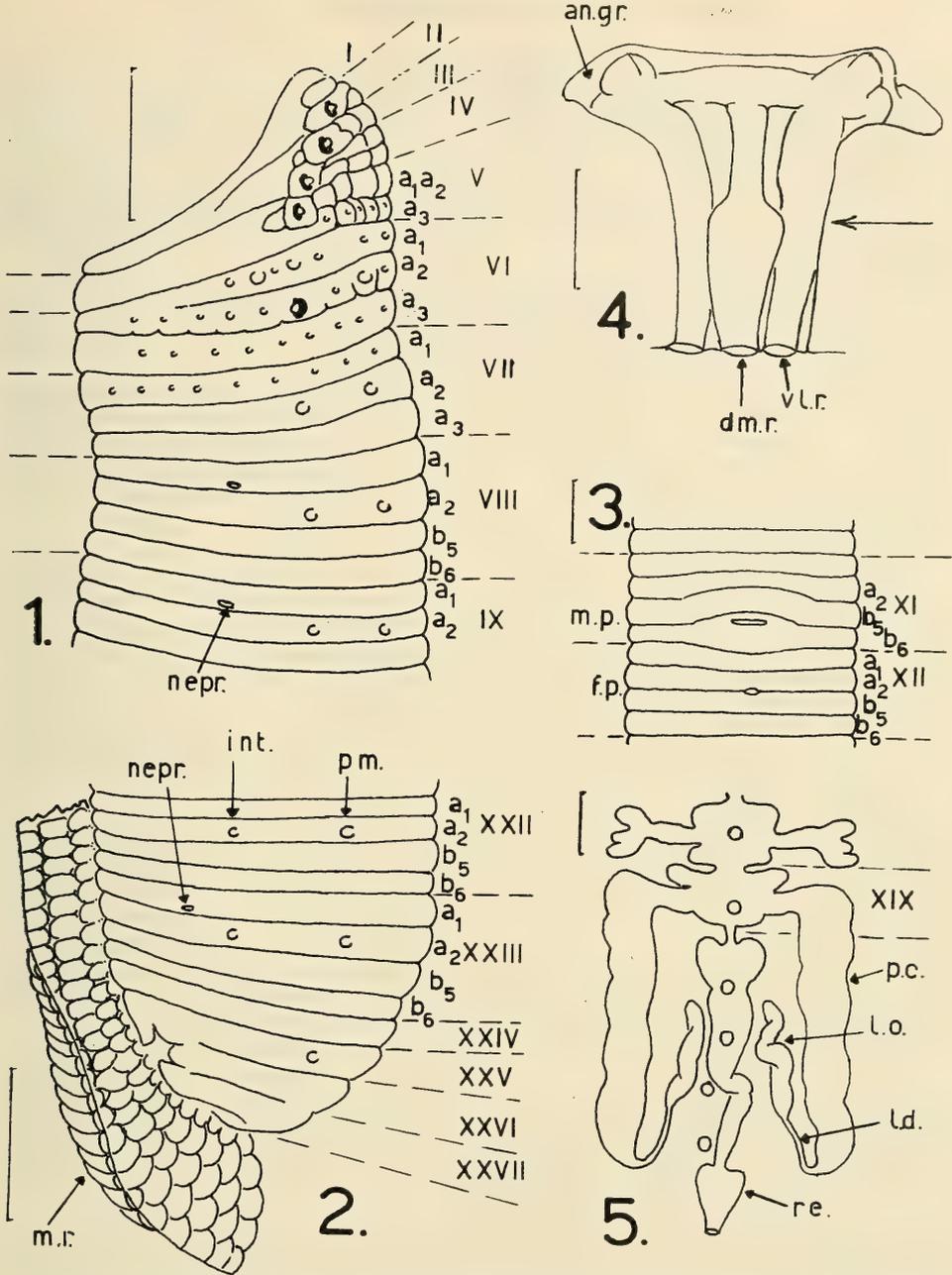


Fig. 1. *Leiodella jawarensis* gen. et sp. nov. 1. Annulation of somites i-ix, left lateral view, sensillae indicated in v-vii. 2. Annulation of somites xx-xxvii; the auricle; posterior sucker; left lateral view. 3. Ventral view of somites xi and xii, showing the location of the genital pores. 4. Annular groove, jaws, entrance to pharynx, and the internal muscular ridges, as exposed by a median ventral incision; arrow marks midpoint in length of pharynx. 5. Caeca of crop, somites xviii and xix, postcaeca, lambertian organs, intestine and rectum.

1.1-1.5 drawn from the type.

Somites and somital ganglia indicated by roman numerals; somital limits, broken lines; annuli, "a₂", etc. Scales equal 1.0 mm.

Abbreviations: an.gr., annular groove; dm.r., dorsomedian muscular ridge; f.p., female pore; int., intermediate somital sense organs; l.d., lambertian duct; l.o., lambertian organ; m.p., male pore; nepr., nephropore; p.c., postcaecum; pm., paramedian somital sense organ; re., rectum; vl.r., ventrolateral muscular ridge.

Leiobdella jawarereensis sp. nov.

(Figs 1, 2, 3)

Type. One specimen, 19.5 mm long. Jawarere Cave, Papua. 14/7/68. Collector W. H. Ewers. Deposited Australian Museum, Sydney, Collection No. W. 4299. Dissected.

Paratypes. Two specimens, 18.0 and 42.0 mm long. Same locality, date and collector as type. Deposited Australian Museum, Sydney, Collection No. W. 4303. Dissected.

Representative material from the same collection has been placed in the Papua and New Guinea Museum and Art Gallery, Port Moresby.

Excepting the reproductive systems, which are detailed from the paratypes, the following account is based on the type.

General form. In a preserved state, moderately contracted; the body generally low convex across the dorsum, the margins obtusely rounded, the venter flat; widest along the posterior half of the body, reducing gradually in width anteriorly to form a narrow short region, a base for the wider anterior sucker which is about two-thirds of the maximum width of the body; posteriorly, narrowing abruptly along the postnephric somites to form the base for the posterior sucker, which is slightly wider than the body. Richly papillate.

Total length, 19.5 mm; the anterior sucker, 3.6 mm wide at v/vi; the body, 2.8 mm wide and 2.0 mm deep at viii/ix, 3.0 mm from the tip of the velum, 5.2 mm wide and 3.5 mm deep at 10.0 mm from the tip of the velum, 6.0 mm wide and 4.0 mm deep at 14.0 mm, and of these dimensions to xxii a_2 ; narrowing then to the base of the sucker, 2.0 mm wide at xxvii, 18.0 mm from the velum; the posterior sucker, 5.8 mm wide and 6.0 mm long.

Colour. Preserved in alcohol. Immaculate, opaque china-white on all aspects without dark pigment other than in the retinal cells of the eyes and a few spaced small erratic patches lateral to the ocular arch.

Pattern. There is no indication of any pattern.

Annulation (Figs 1.1, 1.2, 1.3). Interannular and intersomital furrows equivalent and somital limits not directly recognizable.

Richly ornamented with low obtusely-rounded papillae, most being marked with a white sensory patch. Papillae arranged as a transverse row on each annulus, large and small on the dorsal and lateral aspects, only small on the venter; the large papillae appearing as though arranged in sinuous longitudinal lines which are not recognizably related to the lines and fields of the somital sense organs. In somite xvi, each annulus carries about 25 to 27 papillae.

The somital sense organs of the dorsal and lateral aspects are most difficult to recognize as longitudinal series, and cannot be recognized with any confidence on the venter. Confusion comes from the fact that b_5 is by far the longest annulus in most somites, and it is only with the identification of a_1 by the presence of the minute and obscure nephropores that the somital annulation can be analysed. The nephropores are central in a_1 in anterior somites and close to the posterior edge of the annulus in posterior somites.

There is a soft narrow rounded rim on an undivided thin semitransparent membrane which forms the lateral and ventrolateral wall of the chamber lateral to somites i-iv and anterior to v, which in turn forms the ventral portion of the margin of the sucker, and which, with vi, completes the wall of the chamber of the sucker. There is a transverse row of some eight large white sense organs on the dorsal portion of the rim of the sucker.

A weak but distinct short furrow extending across the median field separates somite i from ii; ii, uniannulate, the first pair of eyes, as also the eyes in iii and iv, located each in a large areola, and some areolation also in i, ii, iii, with indications of areolation in iv and v in the median and paramedian fields; iii, uniannulate, with the second of eyes; iv, 2-annulate between the ocular areolae, the third pair of eyes in $a_1 a_2 = a_3$; v, incomplete 2-annulate, the fourth pair

of eyes in $a_1 a_2 > a_3$, the furrow $a_1 a_2 / a_3$ terminating at the ocular areolae, v uni-annulate below this and forming only the ventral margin of the sucker; vi, incomplete 3-annulate, $a_1 = a_2$ slightly $> a_3$; the fifth eyes in a_2 , the furrow a_1 / a_2 extending into the marginal area, and vi 2-annulate across the venter; vii, 3-annulate, $a_1 = a_2$ slightly $> a_3$.

Somites viii-xxii complete 4-annulate (total, 15); the midnephric series with $a_1 < a_2 = b_5 > b_6$ or $a_1 < a_2 < b_5 > b_6$.

The first nephropores lateral on viii a_1 .

Somite viii, $a_1 = a_2$ slightly $< b_5 > b_6$; ix, $a_1 < a_2 < b_5 > b_6$; x, not assessable; xi, $a_1 < a_2 = b_5 > b_6$, as also xii; xiii, $a_1 < a_2 = b_5 ? b_6$; xiv, $a_1 < a_2$ slightly $< b_5 > b_6$, as also xv; xvi to xxii, with $a_1 < \text{or slightly } < a_2 < b_5 > b_6$ (and $b_6 >$ than the following a_1); xxiii, incomplete 4-annulate, a_1 slightly $< a_2 > b_5$ slightly $> b_6$, the last pair of lateral nephropores close to the posterior edge of a_1 , and xxiii a_2 the last annulus fully formed across the venter, b_5 and possibly b_6 cross the venter as very thin ridges.

Somites xxiv, xxv, xxvi, xxvii, incomplete uniannulate. Anus at the posterior border of xxvii.

Auricles, relatively small, restricted to the lateral ends of xxv, xxvi, xxvii; xxv expanding into a poorly-formed anterior pointed lobe; xxvi, shorter, pointed, and bridging between the anterior lobe and the larger rounded posterior lobe which is formed by xxvii. The auricles roof over a small but distinct cavern.

The dorsum of the posterior sucker carries some six concentric rows of papillae. The ventral surface has a small central papillate disc, about one-quarter of the diameter of the sucker, and radiating from the disc are muscular ridges which subdivide to end as about 100 ridges on the margin of the sucker. The clamp, small, acutely triangular.

Genital pores, male anterior in xi b_6 ; female, xii a_2 / b_5 .

Alimentary tract (Figs 1.4, 1.5). Central in the disc of the anterior sucker is a small transversely oval aperture, 1.0 mm wide. This is at the level of vi/vii, immediately anterior to the ventral portion of the anterior ganglionic mass which is compact, almost globular, and separated from the first independent ganglion (vii) of the nerve cord by a space approximately equal to the length of the ganglion.

The rim of the oval aperture is rounded, and the rim continuous with a thin membrane.

A median ventral longitudinal incision shows a very well-developed deep wide annular groove internal to the aperture, the anterior wall of the groove being formed by the thin membrane and the posterior wall by the entrance to the pharynx and the jaws.

There is no jaw or muscular pad in the dorsomedian position. The dorso-medial and dorsolateral portions of the entrance to the pharynx have the appearance of a narrow transverse flat uniformly muscular band, continued posteriorly as an initially narrow dorsomedian primary internal muscular ridge, wider in the posterior half of the pharynx and without indications of secondary subdivision.

The two ventrolateral jaws are narrowly separated ventrally, housed in the annular groove without any indication of crypts or pockets; each jaw, minute, the height of the medial aspect about 0.2 mm, the width of the base about 0.3 mm, and this aspect obtusely rounded in profile; the dental margin about 0.3 mm long, armed with a single row of minute sturdy teeth which appear to be spaced, taller at the median end, and the height diminishing along the row. (Because of the small size of the jaw, this could not be removed for a count of the teeth. No teeth were seen on jaws dissected from other specimens.)

Each jaw continues posteriorly as a primary internal muscular ridge, initially wide, then narrowing in the posterior half of the pharynx.

There are no dorsolateral or ventromedian internal muscular ridges.

The entrance to the pharynx appears wide in the absence of a dorsomedian jaw. The lumen is tubular, tapering.

Salivary glands are sparse, located in vii-ix, without any indication of dorsal columns of aggregated ducts.

The pharynx terminates at viii/ix followed by the compartmented crop; the compartment in ix, simple; in x, xi, each with a small caecum at the median level on each side; xii, ?; xiii and posteriorly including the postcaeca, containing coagulated blood, the casts indicating a pair of primary caeca at the median level extending into and lobed in the paramedian chambers, an anterior pair of small simple caeca retained in the median splanchnic chamber, and also possibly a posterior pair of small simple caeca.

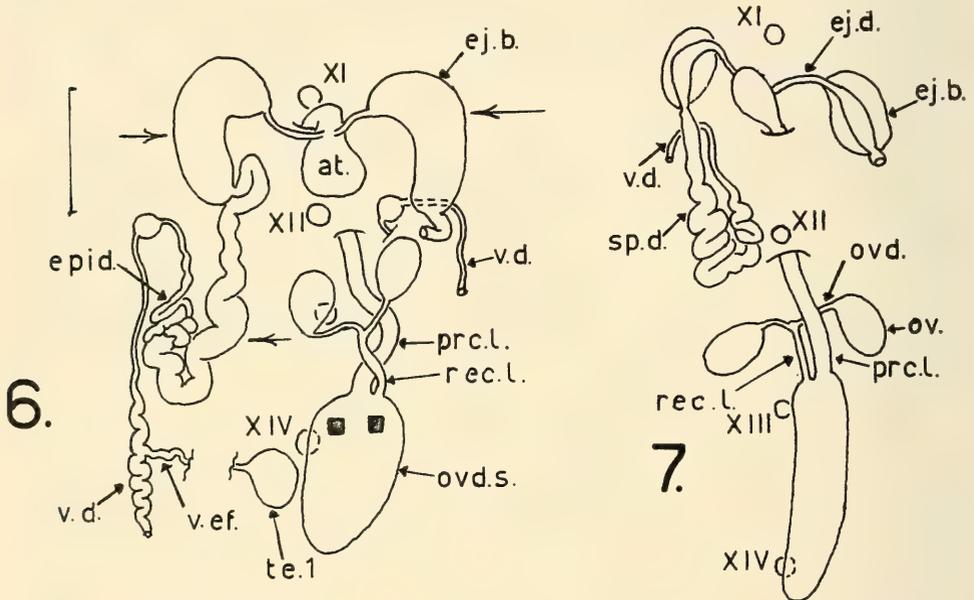


Fig. 2. *Leiobdella jawarereensis*. Anterior region of male paired duct; male median region and female reproductive system of paratypes. 6. Strongly contracted 18.0 mm specimen, male atrium turned posteriorly to show the termination of the ejaculatory ducts; arrows indicate dorsal aspect of sperm duct and ejaculatory bulb, and black squares indicate the original position in the median chamber of the posterior end of the primary loop on the anterior regions of the male paired ducts. 7. Fully extended 42.0 mm specimen.

Abbreviations: at., atrium; ej.b., ejaculatory bulb; ej.d., ejaculatory duct; epid., epididymis; ov., ovary; ovd., oviduct; ovd.s., oviducal glandular sac; prc.l., procurrent limb, female primary loop; rec.l., recurrent limb, female primary loop; sp.d., sperm duct; te., testis; v.d., vas deferens; v.ef., vas efferens.

The compartment in xix with postcaeca originating at the median level and extending into the paramedian chambers, each postcaecum reducing in the posterior half of xxiii to form a narrow duct which passes through the paramedian palisade of dorsoventral muscles into the median splanchnic chamber, then anteriorly to the level of xxii/xxiii, where it expands into the elongate cylindrical lambertian organ which terminates bluntly at about xx/xxi. The lambertian organs are parallel, ventral to the intestine.

The lambertian duct is relatively short; the lambertian organ is about twice the length of the duct.

The compartment in xix reduces to be narrowly tubular, connecting terminally at xix/xx to the much wider intestine which commences with a bilobed

chamber in xx, continues posteriorly as a tapering tube connecting at xxiii/xxiv to the short tapering rectum.

Reproductive systems (Figs 2.6, 2.7). Detailed and figured from the paratypes.

Haemadipsoid: the anterior region of the paired male ducts reflected in the median splanchnic chamber on a posteriorly directed loop; ejaculatory bulbs, present; male median region, a weakly muscular atrium; female median region formed on a posteriorly directed loop with a glandular asymmetrical oviducal sac.

Genital pores, xi $b_5/b_6(b_6)$, and xii a_2/b_5 .

The type, male, mature, the organs strongly compacted, and in general unsuitable for detailed description. Dissected sufficiently to establish that the morphology and relationships of the reproductive systems agree with the following description based on the dissection of an 18.0 mm contracted specimen and a 42.0 mm extended specimen.

Two facts should be noted. Both the anterior region of the male paired ducts and the median regions are located in the median splanchnic chamber ventral to the crop; the anterior region of the male paired duct and the female median region are anchored anatomically only at the anterior ends and are subject to displacement posteriorly on contraction.

The distinct paired small sacs on the vas deferens in xii in the 18.0 mm contracted specimen are new to me. They are not present either in the type or in the 42.0 mm extended specimen. They are located on the duct in the paramedian splanchnic chamber at the point where the duct passes through the paramedian palisade of dorsoventral muscles. They might possibly be a temporary artefact, a consequence from a strangulation of the duct in contraction.

Testes sacular, 10 pairs in the median chamber, the most anterior pair in xiv; each testis connecting laterally by a short vas efferens to the tortuous white vas deferens in the paramedian chamber; the vas deferens, reducing in diameter in xiii, continuing as a very narrow (diameter less than 0.1 mm) thin-walled semitransparent straight duct which passes through the paramedian palisade in xii and extends in the median chamber as a posteriorly directed loop reflecting at xii/xiii or in xiii.

The initial half of the recurrent limb of the loop is a thin-walled narrow duct, slightly tortuous as though a poorly defined epididymis, continuous with the tortuous much-folded wider thin-walled sperm duct which completes the initial limb, increasing in diameter as it passes around the elbow of the loop and becomes loosely folded along the greater length of the procurvent terminal limb to about xi/xii, where it narrows abruptly before joining the ejaculatory bulb.

The right and left loops of the male paired ducts are parallel, not tandem, in arrangement, and the posterior portion of each loop forms a large globular mass dorsal to the female system.

The ejaculatory bulbs are stoutly fusiform, muscular, opalescent, terminating obtusely; the duct continues as a narrow opalescent ejaculatory duct which connects to the anterior aspect of the basal portion of the male atrium. The right and left ducts enter independently.

The male atrium is small, extending above the ventral nerve cord, and the wall is thinly muscular.

The female reproductive system is contained wholly within the median splanchnic chamber.

The ovaries are pyriform, situated in the contiguous annuli of xii and xiii, each connected by a short oviduct to the recurrent limb of the median region which is formed on a posteriorly directed primary loop reflecting in the posterior annuli of xiii or at xiii/xiv.

The recurrent limb is thin-walled, narrower than the strongly muscular procurent limb which terminates at the genital pore and is twice or more the length of the recurrent limb.

The oviducal glandular sac expands from the posterior aspect of the elbow of the primary loop and terminates obtusely in xiv.

No distinct, i.e. compact, albumin or prostatic glands were recognizable.

Additional material. Australian Museum, Sydney. Collection No. W. 5421. Musgrave River area, Central District, Papua. Inside cave. 28.ii.1960. Collector J. Barnaby. Ex Collection No. c/6, Department of Agriculture, Port Moresby. One specimen, 32.0 mm long. *Leiobdella jawarerenensis*. Determined L. R. Richardson, 1973.

Discussion. *Leiobdella jawarerenensis* is one of the large 4-annulate leeches. Fully extended specimens measure up to 55.0 mm. It is variable in appearance. Strongly to moderately extended specimens are distinctly papillate, each papilla tipped with a white sense organ. Fully extended specimens are smooth; somital sense organs and sensillae showing as small white patches, of much the same size; interannular furrows, weak and difficult to identify; some but not all of the testes showing through the ventral body wall.

Cavernicola have been the basis for much speculation on adaptation and isolation as factors inducing directive or non-directive evolution.

The troglobites, animals committed to persistent darkness, constant temperature and humidity, and a diet restricted because it is not mediated by photosynthetic plants, include animals from many phyla. Among these, the common reduction of visual organs, the loss of cutaneous pigment and other associated changes are taken as major evidence of convergent regressive evolution.

As a sanguivorous land-leech, *L. jawarerenensis* is an interesting addition to this area of speculation. It inhabits the aphotic zone. This fact and the fact of the absence of general cutaneous pigment, qualify it for classification as a troglobite. I am unable to point to any other feature which supports this classification.

The eyes are not obviously reduced and the retinal cells are pigmented, both as in some other troglobites. In the study of the land-leech in the bush I reached the conclusion (1968) that vision has no part in bringing the leech to the host. *L. jawarerenensis* provides further evidence in support of this conclusion.

Dr. Ewers informs me that the portion of the cave inhabited by this leech is tunnel-like, reducing to a height of four feet at one place where there are some six leeches to the square foot. Swiftlets, fructivorous bats and insectivorous bats enter the cave. No vertebrate other than the insectivorous bat enters the region occupied by the leech. The leech pays no attention to human beings.

Photographs sent to me by Dr. Ewers show leeches taking a blood meal from bats. In these photographs the posterior sucker of the leech is attached to the wall of the cave; the body, extended; the anterior sucker attached to the arm, or anterior aspect of the fore-arm, or to the base of the web of the hand.

In reply to my enquiry, Dr. Ewers informs me that they have never seen a leech entirely attached on a bat. When the bat flies, the leech remains on the wall of the cave.

L. jawarerenensis is accordingly a troglobite obtaining its nutriment from a host which finds its food beyond the limits of the cave. Blood is a well-balanced tissue, its composition held within the close limits necessary for the well-being of the animal. Other than a monotony of diet, in the sense that *L. jawarerenensis* feeds from only one host species, the nutrition does not differ from that of the land-leech in the bush.

I have shown (1968) that the land-leech in the bush has a closely defined habitat preference. Activity is dependent on soil moisture and humidity, the leech becoming inactive when these are low and anhydrobiotic in drought.

In many collections from the field, the majority of the crops are empty. When engorged land-leeches are held in captivity, the crop contains blood for six to nine months after the meal. The indications are that blood meals are few and widely-spaced for the land-leech in the bush, a circumstance arising both from the task of finding a host and from its varying periods of inactivity.

Dr. Ewers informs me that most of the Jawarere leeches contain blood. This is the case for the specimens he has sent to me. From this it seems that the stable environment of the cave permits long periods of activity, even possibly continuous activity with a host which is readily available.

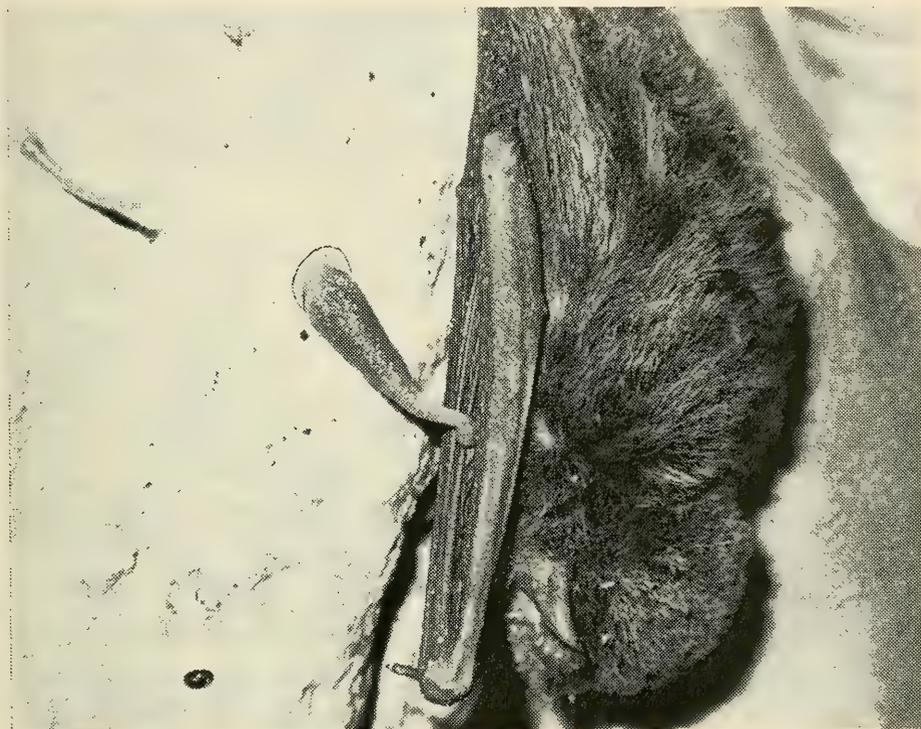


Fig. 3. *Leiobdella jawarereensis* feeding from an insectivorous bat in the Jawarere Cave. Photo: A. Johnstone.

The presence of this land-leech in the aphotic zone raises the usual queries as to the manner in which the troglobite becomes committed to this zone. In this case, the survival of the leech is wholly dependent on the presence of the insectivorous bat.

I have provided (1968) the basis for showing both that the land-leech is a poor traveller, and that a land-leech population is restricted to the limited area of a suitable habitat. From this it becomes difficult to regard the land-leech as an animal capable of active dispersal. This would require travel through environments unsuitable for activity on the part of the leech.

Land-leeches are known in the vestibule of caves. In the case of *L. jawarereensis*, the invasion of the aphotic zone can be assessed as having high probability since the uniformity of the cave environment does not provide

barriers to the active dispersal of the leech. It required only that the leech come into an area occupied by a suitable host animal for a community to be established.

The alternative is that the leech was brought to this part of the cave by passive transport on the host animal. The probability for this can be assessed as very low, unless the bat behaves in a manner differing from other insectivorous bats, e.g. crawls over the ground or climbs through low vegetation in leech-infested areas in addition to feeding on the wing. If there is such behaviour, the probability continues to be low because of the manner in which the fed leech readily departs from the host.

In either case, it seems that the population of *L. jawarerenis* in this cave is isolated.

The land-leech is a convenient laboratory animal. *L. jawarerenis* is a troglobite suitable for experimental studies. It would be valuable to use leeches from this cave to study the consequences both of a varied diet and of exposure to light, in order to see if these lead to the establishment of general cutaneous pigmentation.

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I am grateful to the Australian Research Grants Committee, whose award for studies of the zoology of the Australian freshwater and terrestrial leeches assisted this research.

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SIR WILLIAM MACLEAY MEMORIAL LECTURE, 1974*

“ A SOCIETY OF NATURAL HISTORY. I HOPE
THEY MAY SUCCEED.”

The First Hundred Years

RUTHERFORD N. ROBERTSON †

The title I chose for my Macleay Memorial Lecture on the occasion of the centenary year of the Society is a quotation from Sir William Macleay (1874) himself: “ A Society of Natural History. I hope they may succeed ” and my sub-title is “ the first hundred years ”. Perhaps I should have added “ and the future ”. I hope to develop the idea of continuity of achievement in the past and promise for the future which, I believe, will be even more exciting.

One hundred years ago yesterday, 23rd April 1874, William Macleay was at the North Shore Steam Ferry wharf, Circular Quay, at eight o'clock in the morning to meet his guests for a fishing party. His diary tells us that in a short time all were mustered and having got their provisions, etc., on board they made a good start (Fletcher, 1920). This fishing expedition was one of a series of events in the year 1874 which was to have profound effects not only for this Society but also for science in Australia and, indeed, for science generally. The fishing picnic was in honour of the scientific visitors of HMS *Challenger* which had arrived in Sydney on 6th April. The party consisted of Professor Wyville Thomson, the scientific leader on board the *Challenger*, and Mr. Murray, his Assistant, a physicist; the local guests were Professor Badham (Classics), Mr. Stephens (later Professor), Captain Onslow, Mr. Mackay, Mr. Masters, Dr. Cox, Mr. Forster (a grazier) and William Macleay. Of that party, Stephens, Onslow, Cox, Mackay and Macleay were to become members of the first Council of the Linnean Society of New South Wales when it was founded later in the same year. The coat of arms of HMS *Challenger* now belongs to the Australian Academy of Science.

On the picnic day they called at HMS *Dido* for Captain Chapman and then at Point Piper for Ned Hill who brought with him a blackfellow and a lot of dynamite-torpedoes for fish—it is not recorded whether the blackfellow or the dynamite-torpedoes had more success. Two nights later, one hundred years ago tomorrow, the Captain and the scientific leader on board the *Challenger* returned the hospitality with a dinner at 6.30 p.m. for Macleay, Onslow, Badham, Hill, Cox, Morris, Captain Chapman and Captain Macleay. Macleay's diary records: “ we had a good dinner, spent a most delightful evening and had a look at some of the current things collected. It was 11 o'clock before we left ”. The *Challenger* was sent out by the British Government on a circumnavigating scientific exploration of the sea in the years 1872 to 1874. A steam corvette of 2,036 tons, she was furnished with every scientific device for examining the sea from surface to bottom—natural history work room, chemical laboratory, aquarium, etc. It is not difficult to imagine the immense stimulus which this visit gave to those interested in natural history in Sydney.

* Delivered on 24th April 1974, at the University of Sydney, on the occasion of the celebration of the Society's centenary.

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It is interesting, now, to think about the Sydney in which these picnics and this dinner on board the *Challenger* were taking place. Its population was about 140,000—not very different from the size of Canberra today but so different in design. There was no need for an artificial lake to enhance its beauty but the unplanned city whose streets and roads grew along the old bullock-dray tracks stirred Richard Twopenny (1883) to say here a little later : “ One feels quite angry with the town for being so unworthy of its site ”. The size and handsomeness of the individual buildings were lost in the narrow Sydney streets and the people, said Twopenny, “ succeed in looking pre-eminently dowdy ”. To move from one part of Sydney to another, you would have ridden on steam trams which had been introduced in 1869. The Sydney Ferries Company was in its palmy days and the main means of transport was by sea. In 1876 Sydney had 571 registered vessels of which 176 were steamers (Birch and Macmillan, 1962). You would perhaps have been able to afford a ride in a hansom cab, though most of us would have belonged to the classes for which such fares would have been a luxury, for it was a time of great contrast between wealth and poverty.

Macleay, who had had a good education, had succeeded in his own activities with his wool-growing in the country but had moved to Sydney when he was elected to Parliament in 1855, first as Member for the Lachlan and Lower Darling, but later as Member for the Murrumbidgee. He would have been very familiar with the river at Wagga. He was a member of the select committee which prepared a report in 1866 “ on the distress at present existing among the working classes ”. David Macmillan (1957) records that at that time conditions in the older parts of Sydney, especially around the docks of Darling Harbour, were horrific. The water supply was filthy, germ-infested and inadequate. Under a crust of hopeful respectability was a world of vice, crime and hopeless poverty which makes the worst in contemporary social conditions seem mild.

In the 1870's the city was lit by gas introduced some thirty years before ; only in 1874 was this lighting being extended to Redfern. In the 1860's the railways had gradually pushed out from Sydney and the southern railway, on which William Macleay would have travelled towards his station on the lower Murrumbidgee, had gone as far as Goulburn. In 1870 he had served on another select committee on the “ best mode of facilitating the inland traffic and extension of the railways generally ”. Victoria had already pushed its railways to the border at Albury but it was to be some time before the New South Wales railways extended to that area.

The capital cities of the colonies had been in touch with each other by telegraph since 1858 and in 1874, with the completion of the transcontinental telegraph line from Adelaide to Darwin, telegraphic communication with Europe was established. Other developments too were taking place. Marcus Clark was publishing *For the Term of his Natural Life*. At Sydney Hospital some of the medical staff resented the authority being assumed by nurses and the Chairman of the Hospital Council, William Windeyer, had to write to Florence Nightingale about the place of the nurses, some of whom she had trained (Birch and Macmillan, 1962). In her reply she said “ a man can never govern women ” and advised that the matron's power should be increased ; advice which was followed. Elsewhere, Australia was still very much in the process of development. John Forrest had completed his long walk from Perth to Adelaide in 1870. As Macleay held his fishing picnic, Warburton was just back in Adelaide after more than a year crossing from Alice Springs to the west coast under conditions of almost incredible hardship. In Adelaide, the University was in its first year.

On the world scene, science was just emerging into that strong development which characterised the last part of the nineteenth century. It was only fifteen years after the publication of *The Origin of Species*, the greatest biological event of all time. Those interested in natural history in Sydney were avidly reading

the thrust and counter-thrust of the sometimes violent debate which took place on Darwin's revolutionary views. They did not know then that nine years earlier that quiet monk who was also a scientist, Gregor Mendel, had published a most important paper in the Proceedings of the Natural History Society of Brün, which not to be discovered by the scientific world until the year 1900.

Sir Joseph Dalton Hooker, who had visited Australia with Ross on HMS *Erebus* on the way to the Antarctic, was now President of the Royal Society of London and Director of Kew Gardens. With his interests in the varied flora which he had seen, particularly in Tasmania, he was largely responsible for the work undertaken by Bentham who was second only to Hooker amongst nineteenth century British systematists. The collaboration between Bentham and von Mueller resulted in *Flora Australiensis*. The seventh and concluding volume of this great work which was some sixteen years in progress was not published until 1878. In first part issued in 1863, Mr. Bentham expressed an intention of forming a supplementary volume to contain an account of new species added to existing knowledge during the progress of the work. In 1878 we read that owing to increasing age and infirmity, Mr. Bentham found himself unable to undertake the amount of literary scientific labour involved in such a task and hoped that Baron von Mueller would complete their joint enterprise.

The Reverend W. B. Clarke was nearing the end of his long and productive life devoted to the geology of Australia. When he died in his eighty-first year in 1878, he was putting the last touches on his work which recapitulated his views and the controversies on the geology of the sedimentary deposits in New South Wales. Despite both the relationships that had been observed in the distributions of some of the flora and fauna of different parts of the world and the developments in palaeontology taking place at a rapid rate at the end of the nineteenth century, there was still no idea that the explanations might lie in the movements of the continents. It was another thirty-seven years before Wegener made his suggestion.

It was only eight years since Pasteur in France had done his famous work in isolating the two disease bacilli from the silkworm; now he was studying the fermentation process in beer. Koch in Germany had developed the techniques for the isolation and study of bacteria generally and two years later was to isolate the bacillus of anthrax. The development of bacteriology at this time had special significance for the Linnean Society because it was undoubtedly an important influence in bringing about the later establishment of the Macleay Bacteriologist.

This then was the intellectual atmosphere of that time, almost exactly one hundred years ago, when William Macleay was dining with the scientists of HMS *Challenger*. He was to have a busy year. He had just been back to his station at Kerarbury, ninety miles west of Wagga near Hay. Both there and in the country through which he journeyed he had been collecting with the curator whom he had recently appointed, George Masters—Mr. Masters, as he always called him—who was to build up the William Macleay part of the collection that had been initiated by Macleay's cousin and uncle. Macleay was thoroughly familiar with the low, level skyline of the Hay plain, broken only by the river red gums and the trees which the squatters had planted near the banks of the slow moving river of muddy water and sluggish creeks. Macleay was now fifty-four years old. He had arrived in Sydney in March 1839. Soon after his arrival he had gone to the station on the lower Murrumbidgee as a squatter with his cousin and there they had had several difficult years. It was not until 1844 with the recovery in the price of wool—as happens today—that they began to have financial success. When he went into politics he decided that he could manage with occasional visits to his property and a permanent residence in the city of Sydney. There the young man of thirty-seven met the much younger woman

of eighteen, the daughter of Sir Edward Deas Thomson, and they were married in 1857. A difference of some nineteen years in their ages and William Macleay's preoccupation with science probably account for the way in which they apparently agreed that she would go to social functions and he would engage himself in science. About a month before the fishing picnic Macleay had been taken, somewhat unwillingly, to the University of Sydney for the ceremony in which his father-in-law, as Chancellor, accepted on the University's behalf the Macleay Collection, which had been started by his uncle, Alexander Macleay, and cousin, William S. Macleay (Fletcher, 1920). His own real interests are shown by the extract from his diary: "Susan attended a ball at Government House. [I] worked alone on the collection till well after midnight. The octopus which Masters brought in this morning is interesting—a new variety. Unfortunately must go out to dinner tomorrow".

When his cousin, William S. Macleay, died in 1865 it was possible for William and Susan to move into the Macleay residence—Elizabeth Bay House—a gracious, beautiful piece of architecture standing in some sixty acres of land. It had been built for Uncle Alexander in the early 1830's to the designs of John Verge. It was a gentleman's residence with an unrivalled situation, before the city it once neighboured engulfed it. There he lived under quite luxurious circumstances—he took his butler on his first fishing picnic in 1874. However, he had by no means lost the tough resilience which had helped him make a success of the outback life, as is shown by an incident in December 1864. Accompanied only by the boy who was driving the buggy, he came upon the bushrangers Gilbert, Hall and Dunn (one of whom had recently killed a policeman). They were holding up the Goulburn coach, several teams and a number of travellers. Rifle in hand Macleay raised the siege and routed the bushrangers. Ten years later he was awarded a gold medal for "gallant and faithful services" during the bushranging period (Fletcher, 1893).

By the 1870's William Macleay was beginning to enjoy his preferred style of life, embracing the thrill of the discovery of a new species and the discussion of matters of scientific interest with his friends. His idea of social life was the Sunday whisky party where intense and eager discussion was part of the gathering. Captain Arthur Onslow, Dr. Cox and others who were to become the founders of the Linnean Society of New South Wales were among those who regularly attended these weekly discussions.

On the 13th October Macleay wrote in his diary: "Dr. Alleyne and Captain Stackhouse are trying to get up a Society of Natural History. I hope they may succeed. Such a Society, embracing all branches of Natural History, and issuing a Monthly Magazine, ought to be both useful and successful" (Walkom, 1925). Thus we find the earliest mention of the Linnean Society. This was followed by a notice of a preliminary meeting to be held in the boardroom of the Public Library on 29th October 1874. There, Macleay was elected as President, Sir William Macarthur as Vice-President, Captain Stackhouse as Honorary Secretary and H. H. Burton Bradley Esq. as Honorary Treasurer of the provisional committee.

The President-elect steered the business of the meeting away from the suggestion that it should be called the Macleayan Society, and the name of the great Linnaeus was commemorated. The President-elect, Mr. W. J. Stephens and Dr. Alleyne were chosen to draft the rules. Some eleven years later Macleay was to say: "Our rules state that the Society is for the promotion of the study of Natural History in all its branches. Few people, I suspect, are aware of the wide significance of that sentence" (quoted by Fletcher, 1893). The first annual meeting of this Society was held in Lloyd's Chambers in 362 George Street on 13th January 1875.

When we look at this first hundred years of our Society, how far can we say with confidence that Macleay's hopes for its success have been fulfilled? I

shall speak for a little while on the kinds of things for which the Society has been responsible and let you judge whether you would regard it as a successful venture. I shall finish my lecture by speculating a little on what might be done in the next hundred years.

There is no doubt whatever that the Linnean Society immediately became a focal centre for scientific activities in the areas of biology and geology in this country. It had significance that went wider than the city of Sydney and the colony of New South Wales, for before long it was truly a national body. This is illustrated splendidly by reference to *The Macleay Memorial Volume* (Fletcher, 1893), published in 1893 to record by scientific publications (which he would have appreciated) the great regard in which the biologists and geologists of Australia then held Sir William who had died in 1891. This volume contains thirteen different scientific contributions; half the contributors were or were to become Fellows of the Royal Society of London, in those days the greatest distinction that could be conferred upon a British scientist. Those writing these papers were the leaders in biology and geology in Australia and New Zealand: the Professor of Biology in the University of Melbourne, Baldwin Spencer, the Challis Professor of Biology in the University of Sydney, William Haswell, the Professor of Geology in Canterbury College, Christchurch, F. W. Hutton and two great men of science, Professor J. T. Wilson, who was then Professor of Anatomy in the University of Sydney and was to become Professor of Anatomy in the University of Cambridge, and Mr. C. J. Martin (later Sir Charles), one of the great physiologists of the British Empire. The famous Baron von Mueller contributed *Notes on an Undescribed Acacia from New South Wales* and *Description of a New Hakea from Eastern New South Wales*. The important and interesting contribution of the Palaeontologist to the Australian Museum and Geological Survey of New South Wales, Mr. R. Etheridge, described the weapons and implements of the Alligator Tribe, Port Essington, North Australia. You will recall that Port Essington failed as a settlement and was later succeeded by Port Darwin. A section in Mr. Etheridge's work describes the "trumpets" of these tribes, made from hollow bamboo—what we call the didgeridoo. Incidentally the bamboo was not indigenous but had been planted by the Port Essington settlers and used by the tribes.

There is no doubt that the success of the Society is reflected in the greatness of the individuals who were associated with it in its early years. The importance of its ability to publish the papers that described the Australian natural history can hardly be overestimated. The first volume of the Proceedings started in the two years 1875/76. Thereafter a volume was published every year so that in the first fifty years of the Society's existence, forty-nine volumes of the Proceedings were published. In those days the publication of these descriptions and of the speculations of our scientific colleagues were, relatively speaking, much more important than they would be today. First, opportunities for publication were more restricted than those now available in the wide range of current journals. Second, the exchange of information between scientific colleagues was much more difficult. Bear in mind that travel was slow and arduous, opportunities for conferences infrequent, that the radio did not exist and that consequently the printed word was the pre-eminent form of communication. In addition to the Proceedings, the Abstracts of Proceedings played an important part in the days when there were so many new forms of naturally occurring objects to be described.

The Society quickly built up a library, some of the early parts of it being due to the generosity of Sir William Macleay. Some of it was unfortunately lost in the disastrous fire of 1882 when the Garden Palace was destroyed. The Garden Palace, which had been built for the International Exhibition of 1879, had been retained as a building both for government offices and society premises. The loss of records, library and microscopes to the Linnean Society as a result of that fire was nothing short of crippling.

It is not my intention, in a short talk, to attempt anything like another historical account of the Linnean Society ; it has been written before (Walkom, 1925). I would, however, like to refer to its success by some examples of the types of men and women who have been associated with it. My selection will show you where my admiration lies.

In 1882 a young Welshman, Tannatt William Edgeworth David, arrived in Australia to take up an appointment as Assistant Geologist-Surveyor in government employ. It was not long before he was a member of the Linnean Society. In 1883 he surveyed the tin fields of the New England district and in 1886, the coal-bearing strata of the lower Hunter Valley in which he discovered the hitherto unsuspected existence of the important coal seams which became the great Maitland Coalfield. In 1891 he was appointed Professor of Geology and Physical Geography in the University of Sydney and assumed his place as a leader in the scientific world of Australia. He was President of our Society from 1893 to 1895 and continued his active geological work first with the expeditions to the coral reefs to ascertain the actual structure of coral, incidentally confirming the theory of Charles Darwin about reef formation, and later with trips to the mountains to consider the effects of glaciation on the Australian continent. Towards the end of 1907 he joined the Shackleton expedition to the Antarctic and not only led the climbing party on the first ascent of Mt. Erebus, no mean feat since it was 13,000 feet in those regions, but also led the small party of himself, Mawson and Mackay to the exact site of the south magnetic pole, which they reached on 16th January 1909. There, following the instructions of Shackleton (1911), they hoisted a Union Jack on a small flagpole and uttered the words, as David's diary says : " I hereby take possession of this area, now containing the magnetic pole, for the British Empire ". At the same time he fired the trigger of the camera, and the string can be seen vibrating in the photograph of the three men at the south magnetic pole. What is not seen is that the flag which they had taken with them was one which had to be made from pieces of cloth from various garments since there was no spare flag on the *Nimrod*. That flag we now proudly possess among the archives in the Academy of Science. They started that long trek on 25th September and were picked up again by the ship *Nimrod* on 4th February. I have quite a personal interest in this distinguished member and former President of our Society who for me was the greatest character of our many great people. When I was a student he used to lecture occasionally, telling the story of the Antarctic adventures to the students' Science Society, and I still remember two things quite clearly. The first was that he said that people who were concerned about his welfare used to say to his wife : " Why ever did you let that poor thin Professor David go to the Antarctic ? He will feel the cold so terribly ! " " But ", said David, " I didn't feel the cold because it's not so important to be fat as to have a good circulation, and I have a good circulation ! " The other thing is his amusing description of how, when they were in their tent and were in great concern about whether they would be picked up by the ship, they heard the ship's gun. The tent door was not made to fit three large men in arctic dress emerging together and they collided and trampled over each other in so doing. After picking themselves up they had not run very far outside the tent when Mawson disappeared twenty feet down a crevasse ; fortunately he was not hurt. It is no wonder that David was welcomed home by a crowded function in the Great Hall of the University of Sydney.

Finally, as though David had not done enough already in his life, he became Chief Geologist to the British Army supervising the practical application of geological knowledge to tunnelling, water-supply and locating deep dugouts throughout the British sphere of operations, winning the D.S.O. in 1918.

One of the characteristics of natural history in the nineteenth century was that the work—including work of great distinction—was often carried out by

people to whom it was more of a hobby than a profession. I have already mentioned Macleay and the clergyman-geologist W. B. Clarke. In this century too there were people of similar devotion to natural history—the Reverend H. M. R. Rupp working on the orchids, Mr. G. A. Waterhouse “the butterfly man”, Mr. S. J. Copland the herpetologist who used to be the night crime reporter for the *Sydney Morning Herald*. I want to mention one name both because of a personal reminiscence and to make an important point. Mr. A. H. S. Lucas was Headmaster of Sydney Grammar School, a member of our Council for many years and President from 1907 to 1909; he was the only person in Australia then to undertake a systematic investigation of our marine algae. He was still on the Council when I, a brash young recent graduate on a Science Research Scholarship of \$120 a year, became an applicant for a Linnean Macleay Fellowship which paid the princely sum of \$400 a year. Some of my friends at Sydney University were speculating on my chances when I said that I was not very hopeful since I was interested in experimental science and the Linnean Council was composed of a number of old fogies mainly interested in “stamp-collecting” biology. I quite forgot that the grandson of A.H.S. Lucas was among those present. Not long after I was awarded a Fellowship I had a message via the grandson, in the form of a question: “Did I think the old fogies sometimes did the right thing?” A splendid rebuff for my youthful arrogance and intolerance. I am glad that I have lived long enough to realise that we need people like Clarke, Waterhouse, Lucas, Copland and others. The reason for the paucity of knowledge of biology and geology in district details in this country, compared with such knowledge in Britain, is that such people are so thin on the ground. The ordinary member here, with his notes and publications, has an important role to play in the establishment of this kind of science.

I could not attempt to enumerate the professional scientists whose outstanding work has been associated with our Society. Among those I personally admire greatly are Professor W. L. Waterhouse of the Faculty of Agriculture, University of Sydney, and Dr. W. R. Browne, who in addition to his distinguished research did so much for the Society.

The Linnean Macleay Fellowships, of course, have made an enormous contribution to the scientific development of this country; at one time they provided opportunities for research which were without parallel anywhere else in Australia. The first Macleay Fellow, H. I. Jensen, appointed in 1905, was to write *The Soils of New South Wales*. The second, J. M. Petrie, held his appointment for eighteen years during which time he raised a family, one member of which was A. H. K. Petrie, the first plant physiologist at the Waite Agricultural Institute and one of our three pioneers of plant physiology. Father Petrie was really a plant chemist with biochemical leanings; he wrote on nitrogen metabolism in plants, a subject which his son was to develop strongly. The third and fourth Fellows later became professors and the fifth, Dr. A. B. Walkom, in addition to being a palaeontologist, became an organiser for science who left not only this Society but also ANZAAS, the former Australian National Research Council and various other bodies permanently indebted to him. Among the other distinguished Fellows were R. J. Tillyard, the entomologist who became a Fellow of the Royal Society and first Chief of the CSIRO Division of Entomology, the late Professor P. D. F. Murray and Dr. I. M. Mackerras, now one of our most revered senior scientists in the Australian Academy. Others are Dr. Lilian Fraser, Professor N. A. Burges, now a Vice-Chancellor, Dr. Ilma Pidgeon, Dr. Germaine Joplin, Dr. June Lascelles, and so on. Present Council members, Dr. Mary Hindmarsh, Dr. Elizabeth Pope and Professor T. G. Vallance have been Fellows.

Incidentally, you will notice a high proportion of female names among those I have mentioned. I am pleased to say that although the Linnean Society

began in the tradition of being a male preserve one hundred years ago, it was reasonably early in breaking through that awful and now almost incomprehensible barrier, the exclusion of women. Women were admitted as associate members in 1885 and as ordinary members in 1909 and the first woman Linnean Macleay Fellow, Miss Irwin Smith, was appointed in 1919.

The Macleay Bacteriologist was the far-sighted scheme of an imaginative man—William Macleay—who endowed the position as a long term appointment. Only four people have held that position ; Mr. Greig Smith for 29 years, Dr. H. L. Jensen for 19 years, Dr. Y. T. Tchan (including the period since the arrangement was made with the University of Sydney) for 14 years and now Dr. K. Y. Cho since 1969. This endowment showed the importance that William Macleay placed upon the coming development of bacteriology as a science. When you think now of all in health, genetics and biology that depends upon our knowledge of the bacterial kingdom—one might almost call it the Third World of biology—you can appreciate the imagination of this man who was associated with our Society in the beginning. If Macleay were to return I think he would be particularly pleased both with his intelligent guess about the importance of bacteriology and with the success of the Macleay Bacteriologists.

I am equally sure that there are some areas where he would be bitterly disappointed in the stewardship of those who have succeeded him. I shall mention only two : one a scientific disappointment, the other a social failure. You will recall that Mr. Bentham completed his work on *Flora Australiensis* in 1878. He specifically stated that the writing of a flora is an ever-changing, never-ending activity and expressed the intention of forming a supplementary volume to contain an account of the new species added to existing knowledge. Now one hundred years later, despite the excellent work in the regional floras and local handbooks, we are still talking about the need for a revised *Flora Australiensis*. True, we have made a modest beginning with some work started by the Academy but we hope it will be stepped up to more vigorous activity by the newly formed Biological Resources Survey sponsored by the Federal Government and under the chairmanship of Dr. D. F. Waterhouse one of our members and the bearer of a well-known Linnean Society name.

I find the social failure quite frightening. In 1866 William Macleay was a member of a Select Committee of Parliament in New South Wales to report on "the distress at present existing in the working classes". In 1972 the Federal Government appointed Professor Ronald Henderson to report on "poverty in Australia" and that survey is still going on. How can we as a community fail to be ashamed that amidst all our affluence we should still be talking about surveying poverty instead of having made some social arrangement to eliminate it? I would not like to have to make excuse for this to William Macleay.

What shall we make of the next hundred years? I cannot be a prophet except of one thing—the next hundred years will be different from the last. The only constant and predictable thing in our world is change but the nature of any change is unpredictable and often startlingly unexpected. Perhaps we can define how our starting point for a hundred years from now differs most from the starting point in 1874. If I asked you to define the most important difference I would get a variety of answers. I am not going to enumerate the obvious changes like those in travel and communication. I want to draw your attention to one vital change. Sir William Macleay said that he thought few people realised the significance of the study of natural history. Natural history was of course the generic phrase used in those days for the biological and earth sciences. Now one hundred years later that statement is no longer true.

A most important difference is that the awareness of science in the whole community is changing and changing rapidly. 1874 saw an age in which only a favoured few escaped illiteracy and scientific ignorance. The ordinary person

today realises how large a part science and its daughter, technology, fathered by science and mothered by industry, plays in his life. A recent survey by the *Sydney Morning Herald* recorded that 49% of those surveyed have great faith in science, 39% had some faith and only 2% had no faith. Today the student in our high schools has courses in science aimed not merely at expanding his knowledge of scientific facts and phenomena but also at giving him the experience of thinking for himself as a scientist thinks. We therefore have some hope that problems will be solved by rational thinking. Some of the unrest among the young is undoubtedly associated with reaction against the older irrational thought and superstitions. There is always some backlash in such circumstances too, since it is more comfortable for some people to cling to superstition than to face realistic reason. There is increasing realisation that science is an all-pervading influence in society. It must be considered not a thing apart but rather as an intrinsic part of our way of thinking—a topic I have dealt with at some length in my Oscar Mendelsohn Lecture (Robertson, 1974). We have therefore an almost explosive increase in the awareness of the methods of science and scientific thought. On the international scene we are witness to the greatest revolution of all time, in China, a country which I visited earlier this year. There, children at school from the age of 6 to 17 are receiving a scientific education specifically directed towards the elimination of the older superstitions with which that country was so rife. It will be interesting to see how this great attempt at egalitarian socialism based on modern science and technology develops. What a contrast to China as it was one hundred years ago; it has emerged from feudalism only in the last twenty-five years.

What will these new starting points in our attitudes to science mean to the Linnean Society? Earlier I referred to the importance of the non-professional scientist in contributing to our knowledge of the flora, fauna and geology of this country. I hope that with our increasing leisure and increasing scientific background there will be a corresponding increase in the number of people associating themselves with bodies like the Linnean Society, better to describe and explain our Australian surroundings in scientific terms. In this way we shall fill the many gaps in our knowledge of this vast continent in which we have nothing like the detailed scientific exploration seen in Britain and other countries of Europe, where every district is so well-known and described scientifically. In this area the non-professional scientist, equipped with the improved background in scientific training now provided by the high schools, will be able to make a first-rate contribution. I hope that the Linnean Society will continue to act both as a stimulus for such workers and as a publisher of their results. I think there is great room for encouragement of these kinds of activities. I have, for example, just read a quite brilliant little paper summarising personal research on plant chemistry done by a fifteen-year-old high school student.

On the international scene all of us will have an important role to play. We shall be developing science in this country parallel with the urgent need for the development of scientific knowledge and, more particularly, scientific attitudes in our neighbouring countries. I gather that the Council of the Linnean Society, which together with the Royal Society of New South Wales has acquired the new building that will become a Science Centre in Sydney, has given consideration to its possible international significance. Many national scientific bodies are expected to have their headquarters in this Science Centre and there will be opportunities to provide for international scientific visitors and to make contact with the science in the developing countries—an extremely important activity for Australian scientists.

I would have another hope and expectation for the next hundred years: that some colourful and devoted personalities such as those I have described will

emerge, like Macleay, David, Walkom, W. L. Waterhouse, Browne and others, who are just as interesting though with activities suited to their own times, whose work and personalities will be talked about a hundred years hence.

I have been much involved in recent discussions of national science policy which means among other things the best use of science and technology for the welfare of the community. Inevitably the question is: For what purpose shall we use our science and technology? What are the national goals to which we would apply our science? Politicians and others are extremely coy in defining national goals. If you came from outside and looked at our behaviour with detached objectivity, you might well judge our goals to be those of selfish sectional interest or of personal self interest, each man for himself or his group. I wonder if it is too much to expect that some time in the next century we as a nation shall evolve socially to the point of having a united major goal—the provision of equality in welfare and opportunity for each member of our community. If so, science and technology could properly be used to that end. If we were to attempt the fulfilment of this ideal and particularly if we succeeded we should be in a much stronger position to supply help in science and technology to developing countries. Until something of this kind is done we shall never be free of the tensions between the underprivileged and those living in luxury, whether we are talking about individuals or nations, and science and technology will not be used for the advantage of all.

I have tried to show how our Society, starting one hundred years ago, was a creation of its time and of the social conditions in which it was born. I should think that the members of the Linnean Society of the next hundred years who will keep changing with changing thought will be increasingly aware of the fact that science and technology have not been properly used. Even if the Society as such is not involved, certainly as individuals, members will become increasingly involved and will take leading roles in seeing to the proper use of science. For if the world does not increasingly aspire to the ideals of the use of rational thought and scientific attitudes, what can save it?

I owe the Linnean Society a great deal. It was partly to express my gratitude to the Society that I accepted the honour of being Macleay Lecturer for a second time. In the next hundred years I hope that there will be many who will gain as much from the Society as I have done in my forty years of association. If I were here when the Society celebrates its bicentenary, I would accept an invitation to be Macleay Lecturer for a third time so that I could wish the Society as much good fortune for its third hundred years as I now sincerely wish it for the second.

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A NEW SPECIES OF *TYPHLODROMUS* SCHEUTEN (ACARINA :
PHYTOSEIIDAE) FROM APPLE IN AUSTRALIA

E. SCHICHA* AND G. DOSSE†

[Communicated by M. CASIMIR]

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Synopsis

Typhlodromus (Typhlodromus) helenae n. sp. (Phytoseiidae) is described from apple in New South Wales, Australia. It is closely related to *T. (T.) pyri* Scheuten (= *T. (T.) tiliae* Oudemans) and to *T. (T.) setubali* Dosse.

INTRODUCTION

Phytoseiid mites from various plants in Australia have been studied and described by Womersley (1954), but none of these has been found on apple. The species described below was collected from apple trees at Bathurst, New South Wales, and could be mistaken for *Typhlodromus (Typhlodromus) pyri* Scheuten, a predaceous mite found on apple trees in Europe, Canada and New Zealand. A key reference is Dosse (1961). Measurements listed are the mean \pm standard deviation of 20 specimens in microns, if not otherwise indicated.

Genus *TYPHLODROMUS* Scheuten

Typhlodromus Scheuten, 1857, *Arch. Naturgesch.*, 23 : 104–112.

Typhlodromus (Typhlodromus) helenae, n. sp.

(Figs 1–7)

Diagnosis. This species is closely related to *Typhlodromus pyri* Scheuten (= *T. (T.) tiliae* Oudemans) and to *Typhlodromus setubali* Dosse. According to Nesbitt (1951) and Chant (1958, 1959) it keys out to *Typhlodromus pyri*. However, it is distinguished from *T. pyri* by having one tooth (instead of two teeth) on the digitus mobilis and from *T. setubali* by having three pores, instead of four, on the dorsal shield. It is distinguished from *T. pyri* and *T. setubali* by having setae M_2 smooth. The spermatheca differs from that of *T. pyri* by having chitinized lips, a broader macroduct and a cervix without a thin neck; it is similar to that of *T. setubali* but the macroduct is thicker.

The males of the three species differ in length and width and the male of the new species can also be distinguished from that of *T. pyri* by having four pre-anal setae instead of three. The spermatodaetyl is rodlike but does not terminate with an "inverted boot" as in *T. pyri* (Nesbitt, 1951). However, its posterior part ends with a suctorial disc similar to that of *T. setubali*.

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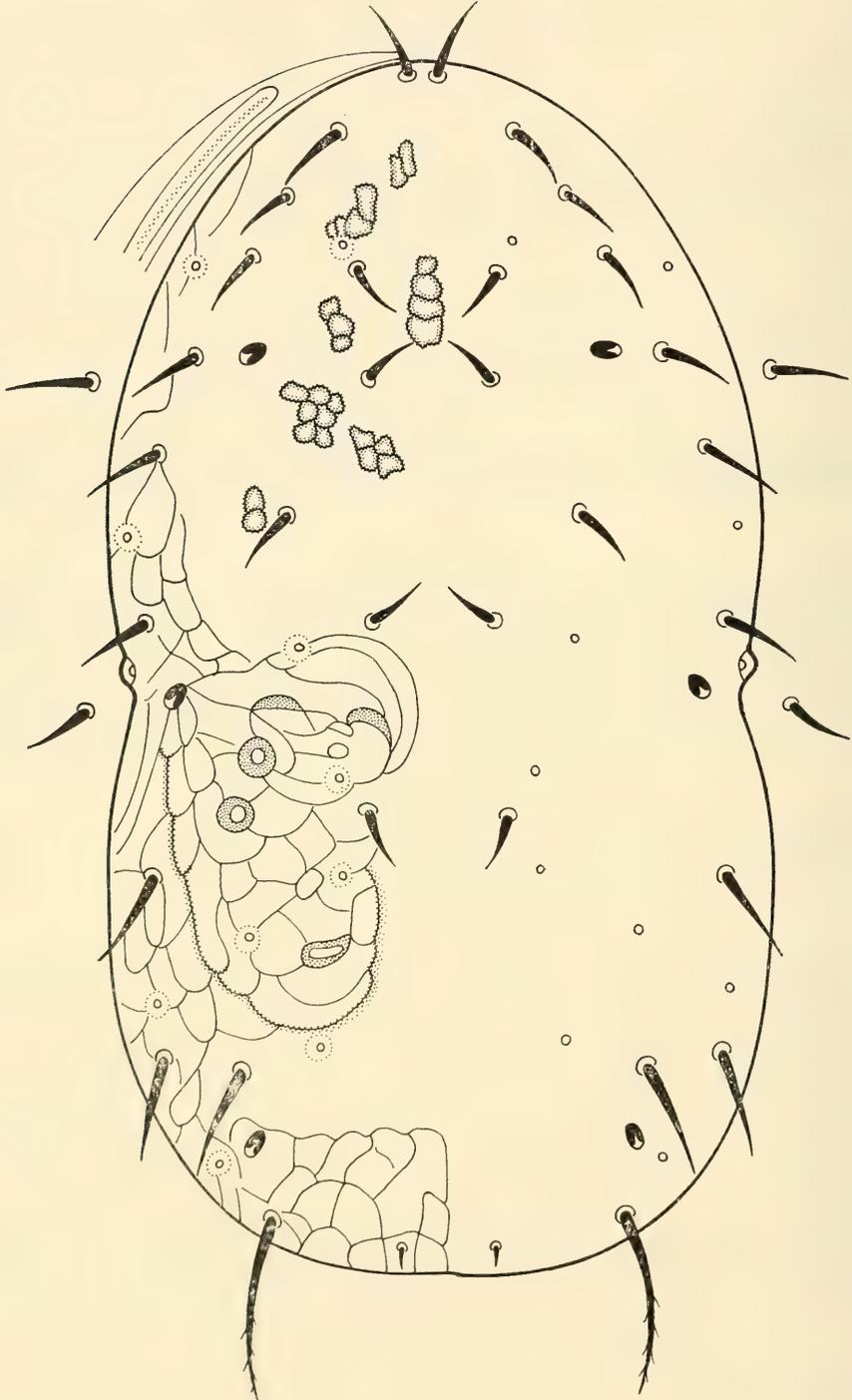


Fig. 1. Dorsal shield of female.

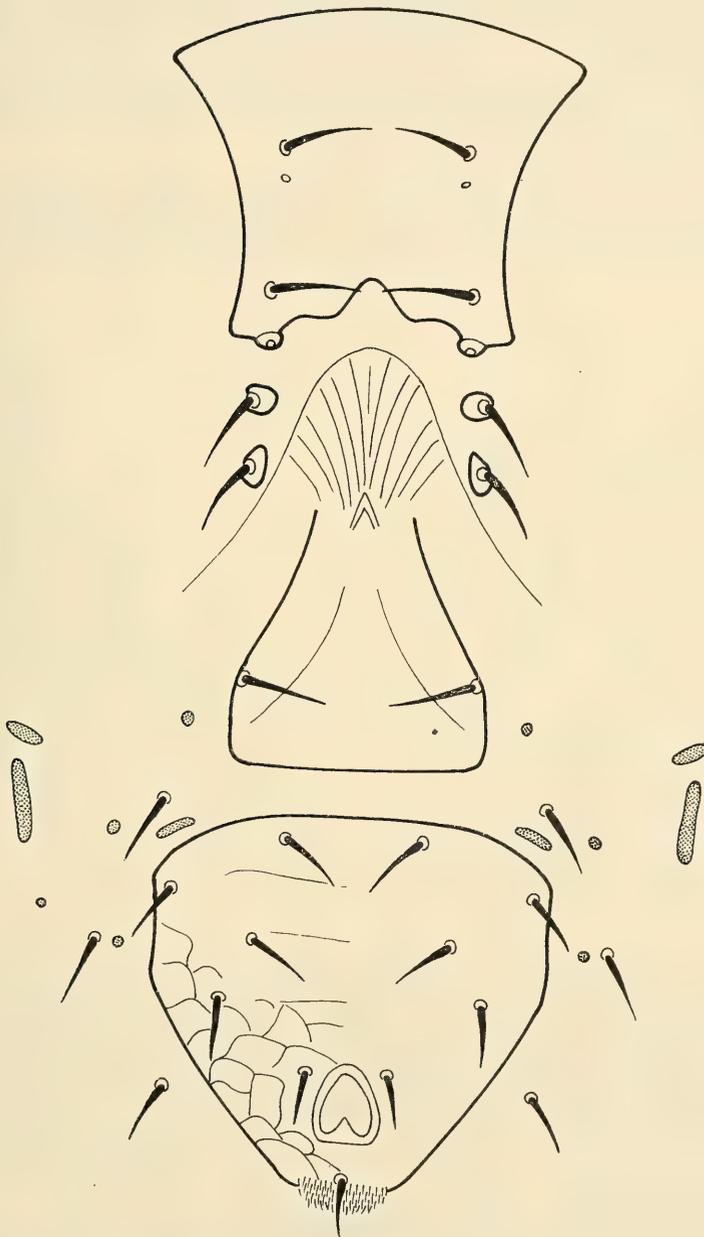


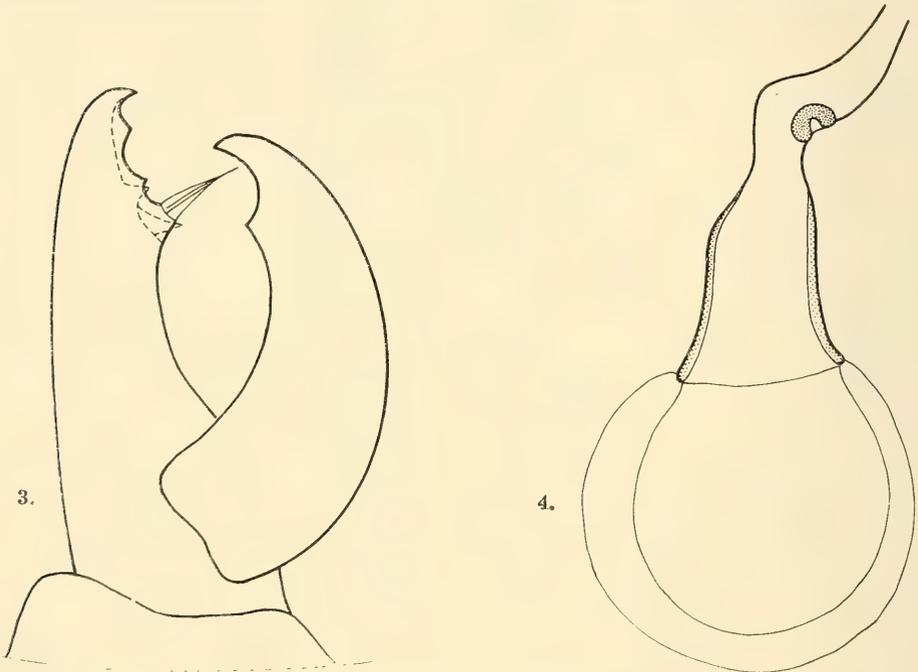
Fig. 2. Venter of female.

Female

Dorsum : Length, 333 ± 7 , width at L_4 179 ± 3 . Dorsal shield (Fig. 1) is imbricated and bears 17 pairs of setae distributed as follows : six dorsal, two median (one anterior and one posterior), six prolateral and three postlateral. These setae measure

$$\begin{aligned} D_1 &= 21 \pm 1, D_2 = 15 \pm 1, D_3 = 14 \pm 1, D_4 = 15 \pm 1, D_5 = 16 \pm 1, D_6 = 5 \pm 1, \\ L_1 &= 22 \pm 1, L_2 = 15 \pm 1, L_3 = 18 \pm 2, L_4 = 19 \pm 2, L_5 = 21 \pm 2, L_6 = 23 \pm 1, \\ &L_7 = 26 \pm 2, L_8 = 29 \pm 1, L_9 = 47 \pm 3, \\ M_1 &= 15 \pm 0, M_2 = 29 \pm 2. \end{aligned}$$

The setae are of moderate length, except D_6 . Setae L_2 are equal to the distance between their bases and the bases of the setae L_3 ; all other setae are shorter than the distances between their bases and the bases of the setae following



Figs 3, 4. 3. Chelicera of female. 4. Spermatheca (of female).

next in the series. Setae M_2 are longer than the distance between their bases and the bases of setae L_8 . All setae are smooth except setae L_9 , which are slightly serrated. There are three pairs of large pores present. One pair is near L_4 , one is postlateral to L_6 and one pair is between M_2 and L_9 . In addition there are 10 pairs of small pores present.

Sublateral setae $S_1 = 20 \pm 2$ and $S_2 = 21 \pm 1$ in length, situated on the dorsal interscutal membrane.

Peritremes extend slightly beyond setae L_1 .

Venter (Fig. 2) : Sternal shield, length 71 ± 1 , width 71 ± 1 , is smooth and bears two pairs of setae. Sternal setae III are situated on small irregularly shaped shields. Setae IV are on irregularly shaped metasternal shields. Genital shield, length 70 ± 1 , width 68 ± 0 , is normal with a pair of genital setae. Ventri-anal shield, length 101 ± 3 , width 102 ± 4 (10 measurements), is shield-shaped with four pairs of preanal setae, and the posterior part is reticulated.

Chelicera (Fig. 3): Fixed digit, length 38 ± 2 (11 measurements), of the chelicera bears four teeth and a pilus dentilis. The movable digit, length 40 ± 1 , bears one tooth on its inner margin.

Spermatheca (Fig. 4): Atrium is knee-like and bears strongly chitinized lips. The funnel-like cervix has a diameter of 17 where it joins the vesicle. Cervix plus vesicle are pear-shaped.

Legs: Only basitarsus of leg IV (Fig. 5) bears a macroseta, 46 ± 2 in length.



Figs 5, 6. 5. Leg IV of female. 6. Ventri-anal shield of male.

Male

Dorsum: Imbricated, length 253 ± 9 , width at L_4 165 ± 4 ; the chaetotaxy and the shape of the setae resemble those of the female. The setae are, however, relatively shorter.

$D_1=16 \pm 1$, $D_2=12 \pm 1$, $D_3=11 \pm 1$, $D_4=12 \pm 1$, $D_5=13 \pm 1$, $D_6=4 \pm 0$,
 $L_1=18 \pm 1$, $L_2=11 \pm 1$, $L_3=13 \pm 1$, $L_4=15 \pm 1$, $L_5=18 \pm 1$, $L_6=19 \pm 1$,
 $L_7=21 \pm 1$, $L_8=21 \pm 2$, $L_9=37 \pm 1$,
 $M_1=11 \pm 1$, $M_2=25 \pm 1$,
 $S_1=15 \pm 1$, $S_2=15 \pm 1$.

Venter: Sternal shield with five pairs of setae and three pairs of pores. Ventri-anal shield (Fig. 6), length 100 ± 2 , width 142 ± 4 (10 measurements), bears four pairs of preanal setae and three pairs of small pores.

Spermatodactyl (Fig. 7): Rod-like and terminating in a small suctorial disc.

Type. Female holotype from Bathurst Agricultural Research Station, New South Wales, Australia (W. G. Thwaite) on leaves of Granny Smith apple trees, 1970. In South Australian Museum, Adelaide, Australia.

Paratypes. Eight females and eight males taken from the same locality as the holotype. Four females plus four males at Biological and Chemical Research Institute, Rydalmere; two females plus two males at Institute for Plant Protection, University of Stuttgart-Hohenheim, West Germany; two females plus two males at South Australian Museum, Adelaide.

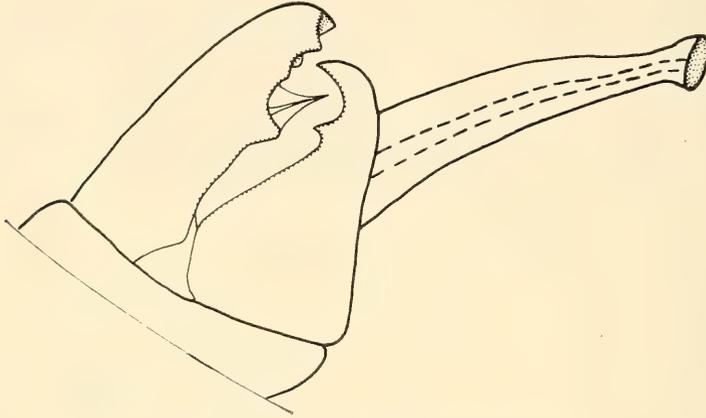


Fig. 7. 7. Spermatodactyl (of male).

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FOUR NEW DAMSELFISHES (POMACENTRIDAE) FROM THE SOUTHWEST PACIFIC

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(Plates III and IV)

[Communicated by Gilbert P. Whitley]

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Synopsis

Four new species of damselfishes which were collected at Indonesia, Melanesia, Lord Howe Island and New South Wales are described. *Glyphidodontops niger* n.sp. was taken at Cape Nelson, New Guinea. It is closely allied to *G. biocellatus*, *G. glaucus*, *G. leucopomus*, and *G. unimaculatus*, all of which are widely distributed Indo-Pacific species. *G. notialis* n.sp. was collected at New Caledonia, Lord Howe Island and New South Wales. It bears a close resemblance to *G. rapanui* from Easter Island. *G. talboti* n.sp. was taken at Indonesia, Solomon Islands, New Hebrides, Fiji Islands and the Great Barrier Reef. It is related to *G. traceyi* from the Marshall and Caroline Islands. *Pomacentrus albimaculus* n.sp. was collected at Madang, New Guinea. It is allied to *P. amboinensis* from the western Pacific.

INTRODUCTION

The damselfishes (family Pomacentridae) are one of the largest families of tropical reef fishes, both in number of species and number of individuals. It is estimated that there are at least 250 species, approximately 150 of which inhabit the seas of Australia and Melanesia. Most of our knowledge of the group in this region is based on the insufficient works of Bleeker (1877) and Fowler and Bean (1928). In 1973 the author made extensive collections of damselfishes at Fiji Islands, New Caledonia, New Hebrides, Solomon Islands, New Britain, New Guinea, the Great Barrier Reef of Australia, and Lord Howe Island. These collections contain 132 species, a substantial increase compared with 85 species reported by de Beaufort (1940) for the region which includes Malaysia, Indonesia, Melanesia and Australia. At least 12 of the species are new, including four species, *Glyphidodontops niger*, *G. notialis*, *G. talboti* and *Pomacentrus albimaculus*, which are described herein.

The Pomacentridae represent an extremely diverse lineage. The majority of Indo-West Pacific members are usually assigned to five major genera: *Amphiprion* Bloch and Schneider, *Dascyllus* Cuvier, *Chromis*, Cuvier, *Abudefduf* Forskal and *Pomacentrus* Lacépède. However, recent studies by the author (unpublished) revealed the necessity for a comprehensive revision of certain genera, in particular *Abudefduf* and *Pomacentrus*. In the South Pacific region 93 of 143 species have been assigned to these two "genera." Under this scheme those individuals with a serrate preopercle margin are assigned to *Pomacentrus* and those with a smooth margin to *Abudefduf*. This arrangement leads to a multiplicity of problems as there are certain groups of species which display intermediate criteria, being characterised by a crenulate or weakly serrate preopercle. A

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TABLE 1
Soft dorsal and anal fin ray counts for new Pomacentrids

Species	Dorsal Rays						Anal Rays					
	11	11½	12	12½	13	13½	14	14½	15	15½	16	16½
<i>Glyphidodontops niger</i>				6								6
<i>G. notialis</i>					1	1	9	1				10
<i>G. talboti</i>	3	11							7	7		
<i>Pomacentrus albimaculus</i>						4					1	1
											1	2

TABLE 2
Pectoral ray, tubed lateral line scales and gill raker counts for new Pomacentrids

Species	Pectoral Rays			Lateral Line Scales						Gill Rakers					
	15	16	17	18	14	15	16	17	18	18	19	20	21	22	23
<i>Glyphidodontops niger</i>				6					6				5	1	
<i>G. notialis</i>			2	7	3				2	5	5		3	5	3
<i>G. talboti</i>	2	12				2	5	7				7	5	1	1
<i>Pomacentrus albimaculus</i>				4					3	1				1	3

revision of the Pomacentridae of the western Pacific, (Allen, in press *a*), reveals there is justification for splitting these groups into at least 13 genera. Surprisingly, most of these divisions were recognised nearly a century ago by Bleeker (1877). *Abudefduf*, as presently recognised, is particularly diverse and obviously constitutes a polyphyletic assemblage. This group is separable into the following genera: *Abudefduf* Forskal, *Amblyglyphidodon* Bleeker, *Glyphidodontops* Bleeker, *Hemiglyphidodon* Bleeker, *Paraglyphidodon* Bleeker, *Plectroglyphidodon* Fowler and Ball and two additional genera which will be described by the author. The genus *Pomacentrus*, as currently recognised, is divisible into *Amblypomacentrus* Bleeker, *Dischistodus* Bleeker, *Eupomacentrus* Bleeker and *Pomacentrus* Lacépède. Most of the species pertaining to this group will remain in the latter genus.

METHODS OF COUNTING AND MEASURING

The methods of counting and measuring are the same as those described by Allen (1972), except the length of the dorsal and anal spines are measured proximally from the base of the spine rather than from the point at which the spine emerges from the scaly sheath. Measurements were made with needle-point dial calipers to the nearest one-tenth millimetre. Standard length is abbreviated as SL. The fraction $\frac{1}{2}$ which appears in the dorsal and anal fin ray formulae refers to a bifurcate condition of the last ray.

The counts and proportions which appear in parentheses under the description section for each species apply to the paratypes when differing from the holotype. A summary of counts for the dorsal, anal and pectoral fin rays, tubed lateral line scales and gill rakers on the first gill arch is presented in Tables 1 and 2.

Type specimens have been deposited at the following institutions: Australian Museum, Sydney (AMS); Bernice P. Bishop Museum, Honolulu (BPBM); British Museum (Natural History), London (BMNH); Muséum National d'Histoire Naturelle, Paris (MNHN); United States National Museum of Natural History, Washington, D.C. (USNM).

DESCRIPTIONS

Glyphidodontops niger, n. sp.

(Plate III, Fig. *a*)

Holotype. AMS I.16708-004, 41.8 mm SL, coll. G. Allen, 26/V/1972, near mouth of Tufi Inlet, Cape Nelson, New Guinea (9°05'S, 149°19'E), 1-2 m, quin-aldine and dipnets.

Paratypes. AMS I.16708-005, 5 specimens, 17.2-30.6 mm SL, collected with the holotype.

Diagnosis. A species of *Glyphidodontops* with the following combination of characters: body depth 2.0 to 2.1 in SL; dorsal spines 13; horizontal scale rows between middle of lateral line and dorsal fin base $1\frac{1}{2}$; predorsal scales reaching level of nostrils; preorbital, suborbital and inferior limb of preopercle naked; teeth biserial; membranes between dorsal spines slightly incised; colour in alcohol uniformly dark brown with intense black spot covering pectoral base.

Description. Proportional measurements for the holotype and two selected paratypes are expressed as percentage of the standard length in Table 3.

Dorsal rays XIII, $12\frac{1}{2}$; anal rays II, 13; pectoral rays 17; pelvic rays I, 5; branched caudal rays 13; gill rakers on the first arch 21 (20); tubed lateral line scales 17; vertical scale rows from upper edge of gill opening to base of caudal

TABLE 3

Measurements of the holotype and two paratypes of Glyphidodontops niger
(expressed in thousandths of the standard length)

Characters	Holotype	Paratype	Paratype
	AMS I.16708-004	AMS I.16708-005	AMS I.16708-005
Standard length (mm) ..	41.8	29.3	25.5
Greatest body depth	498	478	502
Greatest body width	203	184	192
Head length	316	338	353
Snout length	81	82	82
Eye diameter	107	116	126
Interorbital width	96	92	90
Least depth of caudal peduncle	156	154	149
Length of caudal peduncle ..	103	116	102
Snout to origin of dorsal fin ..	431	420	439
Snout to origin of anal fin	694	683	675
Snout to origin of pelvic fin ..	407	399	416
Length of dorsal fin base	615	517	620
Length of anal fin base	254	266	235
Length of pectoral fin	311	273	255
Length of pelvic fin	323	341	306
Length of pelvic spine	184	198	204
Length of 1st dorsal spine	52*	68	82
Length of 7th dorsal spine	163	143	153
Length of last dorsal spine	172	160	165
Length of longest soft dorsal ray	220	205	216
Length of 1st anal spine	86	79	82
Length of 2nd anal spine	165	147	157
Length of longest soft anal ray	239	205	216
Length of middle caudal rays	251	215	235

* damaged.

fin 27; horizontal scale rows from base of dorsal fin to terminal lateral line scale (exclusive of dorsal base sheath scales) 1; from lateral line to anal fin origin 8; predorsal scales about 20, extending to level of nostrils; teeth biserial, those of outer row slender, close-set with flattened tips numbering about 36 in each jaw, inner row of buttress teeth about $\frac{1}{2}$ width of outer row teeth.

Body ovate, laterally compressed, the greatest depth 2.0 (2.0 to 2.1) in the standard length. Head profile conical, the head length contained 3.2 (2.8 to 3.2) times in the standard length; snout 3.9 (4.1 to 4.3), eye diameter 2.9 (2.8 to 2.9); interorbital width 3.3 (3.7 to 3.9), least depth of caudal peduncle 2.0 (2.2 to 2.4), length of caudal peduncle 3.1 (2.9 to 3.6), of pectoral fin 1.0 (1.2 to 1.4), of pelvic fin 1.0 (1.0 to 1.2), of middle caudal rays 1.3 (1.5 to 1.6), all in the head length.

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating one scale row below base of 13th dorsal spine; preorbital, suborbital, snout tip, lips, chin, and isthmus naked; remainder of head and body scaled; scales finely ctenoid; preopercle scale rows 2, inferior and posterior limb broadly naked; small sheath scales covering basal $\frac{1}{2}$ to $\frac{2}{3}$ of membranous portions of dorsal, anal, and caudal fins; margin of preorbital, suborbital, preopercle and opercle entire.

Origin of dorsal fin at level of third tubed lateral line scale; spines of dorsal fin gradually increasing in length to last spine, length of first dorsal spine 3.9 (4.3 to 4.5), of seventh dorsal spine 4.3 to 4.5 (paratypes only, holotype damaged), of last dorsal spine 1.8 (2.1), of longest soft dorsal ray 1.4 (1.6 to 1.7), of

first anal spine 3.7 (4.3), of second anal spine 1.9 (2.3), of longest soft anal ray 1.3 (1.6 to 1.7), all in the head length; caudal fin emarginate, lobes rounded; pectoral fins slightly rounded.

Colour of holotype in alcohol: Head and body dark brown, breast paler, median fins dark brown except posterior portion of soft dorsal and caudal fins pale; pelvic fins brown; pectoral fins pale with black spot covering base and axil.

Colour of holotype in life: Uniformly bluish-black with intense black spot covering pectoral base and axil; pectoral fin translucent.

Individuals under about 30 mm SL are uniformly bluish-black with a series of neon blue stripes on the sides, one per horizontal scale row.

Remarks. *G. niger* belongs to a species complex which includes *G. biocellatus* (Quoy and Gaimard), *G. glaucus* (Cuvier), *G. leucopomus* (Cuvier), and *G. unimaculatus* (Cuvier). These species are sympatric inhabitants of tropical Indo-West Pacific reefs, usually frequenting depths of less than 2-3 metres. They are similar with regards to counts and general body shape, but the adults at least are easily distinguished, both alive and in preservative, on the basis of colour. *G. biocellatus* is characterised by a brown ground colour and single whitish bar, several scales wide, just behind the pectoral fin. The juveniles of this species, as well as those of *G. leucopomus* and *G. unimaculatus* are similar to adult *G. leucopomus* which are predominately yellow with a blue stripe extending from the eye to the soft dorsal fin and with one or two ocelli on the posterior part of the dorsal. The "amabilis" variety of *G. leucopomus*, an ecological variant discussed by Allen (in press, b), is characterised by two or three whitish bars on a dark ground colour. *G. glaucus* is uniformly pale. Adults of *G. unimaculatus* are predominantly brownish with a small black spot at the base of the hindmost dorsal rays. The head and anterior portion of the body is abruptly pale in some individuals ("hemimelas" variety). *G. niger* is the only uniformly blackish member of the complex and also the only species which possess a black pectoral base and axil.

G. niger was encountered at Cape Nelson, New Guinea and Goodenough Island, D'Entrecasteaux Islands. It was relatively common at both localities in areas of moderate surge between 0.5 and 2 metres. The largest individuals encountered were approximately 50 mm SL. The stomach contents of two paratypes indicate an algal diet.

The specific name refers to the characteristic black colouration of the body.

Glyphidodontops notialis, n. sp.

(Plate III, Fig. b)

Holotype. AMS I.17402-008, 49.2 mm SL, coll. J. Randall and B. Goldman, 17/II/1973, off Phillip Point, Lord Howe Island (31°32'S, 159°04'E), 15 m, rotenone.

Paratypes. LORD HOWE ISLAND: AMS I.17357-016, 50.8 mm SL, same data as holotype except coll. G. Allen, B. Goldman and W. Starck, 5/II/1973; AMS I.17358-012, 6 specimens, 44.7-61.3 mm SL, coll. G. Allen and party, 5/II/1973, off west side of Mt. Lidgbird, 20-25 m, rotenone; AMS I.17374-007, 2 specimens, 49.3 and 52.0 mm SL, coll. F. Talbot and party, 18/II/1973, on outer reef between Rabbit Island and Erscott's Passage, 16 m, explosives; AMS I.17377-014, 3 specimens, 28.2-51.5 mm SL, coll. G. Allen and J. Randall, 24/II/1973, North Islet, 25 m, rotenone; BMNH 1973.10.17.4-9, 6 specimens, 51.0-64.5 mm SL, coll. F. Talbot and party, 25/II/1973, on outer reef between Rabbit Island and Erscott's Passage, 12 m; BPBM 15935, 18 specimens, 45.4-64.2 mm SL, same data as preceding paratypes except coll. 26/II/1973; BPBM 15936, 16 specimens, 43.5-62.8 mm SL, same as preceding except coll. 19/II/1973; MNHN 1973-59, 3 specimens, 45.0-52.4 mm SL, same data as holotype except coll. G. Allen, 15/II/1973, quinaldine; USNM 211292, 4 specimens, 24.8-51.9 mm

SL, same data as holotype except coll. J. Randall and party, 26/II/1973; NEW CALEDONIA: AMS I.,17466-001 59.0 mm SL, coll. G. Allen, 15/VI/1973, Puetege Reef, off southeast tip of New Caledonia, 20 m, multi-prong spear.

Diagnosis. A species of *Glyphidodontops* with the following combination of characters: body depth 2.3 to 2.5 in SL; dorsal spines 13; horizontal scale rows between middle of lateral line and dorsal fin base $1\frac{1}{2}$; predorsal scales reaching level of nostrils; suborbital and inferior limb of preopercle scaly; teeth uniserial, dorsal outline uniform without incisions between spines; colour mostly bluish-black (dark brown to blackish in preservative).

Description. Proportional measurements for the holotype and two selected paratypes are expressed as percentage of the standard length in Table 4.

TABLE 4
Measurements of the holotype and two paratypes of Glyphidodontops notialis
(expressed in thousandths of the standard length)

Characters	Holotype	Paratype	Paratype
	AMS I.17402-008	AMS I.17466-001	USNM 211292
Standard length (mm) ..	49.2	59.0	39.0
Greatest body depth	403	436	400
Greatest body width	180	186	180
Head length	298	285	308
Snout length	63	71	72
Eye diameter	103	92	121
Interorbital width	78	75	80
Least depth of caudal peduncle	151	144	146
Length of caudal peduncle ..	103	109	115
Snout to origin of dorsal fin ..	308	336	346
Snout to origin of anal fin ..	608	612	669
Snout to origin of pelvic fin ..	384	398	426
Length of dorsal fin base ..	660	644	577
Length of anal fin base ..	298	312	277
Length of pectoral fin ..	333	310	308
Length of pelvic fin ..	346	305	318
Length of pelvic spine ..	166	159	167
Length of 1st dorsal spine ..	55	54	56
Length of 7th dorsal spine ..	151	153	144
Length of last dorsal spine ..	157	166	151
Length of longest soft dorsal ray	359	322	235
Length of 1st anal spine ..	84	80	87
Length of 2nd anal spine ..	141	125	128
Length of longest soft anal ray	340	322	244
Length of middle caudal rays	241	224	231

Dorsal rays XIII, $14\frac{1}{2}$ (XIII, $13\frac{1}{2}$ to $15\frac{1}{2}$); anal rays II, $15\frac{1}{2}$ (II, $15\frac{1}{2}$ to $16\frac{1}{2}$); pectoral rays 17 (16 to 18); pelvic rays I, 5; branched caudal rays 13; gill rakers on the first arch 20 (20 to 23); tubed lateral line scales 17 (16 to 18); vertical scale rows from upper edge of gill opening to base of caudal fin 28; horizontal scale rows from base of dorsal fin to terminal lateral line scale (exclusive of dorsal base sheath scales) $1\frac{1}{2}$; from lateral line to anal fin origin 9; predorsal scales about 18 to 20, extending to level of nostrils; teeth uniserial, incisiform, about 40 to 44 in each jaw.

Body elongate, laterally compressed, the greatest depth 2.5 (2.3 to 2.5) in the standard length. Head profile conical, the head length contained 3.4 (3.3 to 3.5) times in the standard length; snout 4.7 (4.0 to 4.6), eye diameter 2.9 (2.6 to 3.1); interorbital width 3.8 (3.7 to 3.9), least depth of caudal peduncle 2.0 (2.0 to 2.1), length of caudal peduncle 2.9 (2.5 to 2.7), of pectoral fin 1.0 (0.9 to 1.0), of pelvic fin 0.9 (0.9 to 1.0), of middle caudal rays 1.2 (1.2 to 1.4), all in the head length.

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating $1\frac{1}{2}$ scale rows below base of second to third soft dorsal ray; preorbital, snout tip, lips, chin and isthmus naked; remainder of head (including suborbitals) and body scaled; head scales cycloid, remainder finely ctenoid; preopercle scale rows 2 with additional row of scales on inferior limb; small sheath scales covering basal $\frac{1}{3}$ to $\frac{2}{3}$ of membranous portions of dorsal, anal and caudal fins; margin of pre-orbital, suborbital, preopercle and opercle entire.

Origin of dorsal fin at level of second tubed lateral line scale; spines of dorsal fin gradually increasing in length to last spine; length of first dorsal spine 5.5 (5.3 to 6.3), of seventh dorsal spine 2.0 (1.9 to 2.3), of last dorsal spine 1.9 (1.7 to 2.1), of longest soft dorsal ray 0.8 (0.9 to 1.3), of first anal spine 3.6 (3.2 to 4.1), of second anal spine 2.1 (2.0 to 2.4), of longest soft anal ray 0.9 (0.9 to 1.3), all in the head length; caudal fin forked, the lobes filamentous; pectoral fins pointed.

Colour of holotype in alcohol: Ground colour of head and body dark brown, scale centres slightly lighter; breast and abdomen tannish; median fins dark brown to blackish; pelvic fins dusky with blackish tips; pectoral fins mainly translucent with black wedged-shaped spot covering upper portion of base, axil of fin pale.

Colour of holotype in life: Head and anterior portion of body blue-grey grading to blackish behind pectoral fins; dorsal, anal, and basal portion of caudal fin bluish-black; dorsal and anal fins with bright blue margin; distal half of caudal fin blue; pelvic fins dusky with bluish anterior edge, tips black; pectoral fins light blue with blackish spot superiorly at base.

Remarks. *G. notialis* most closely resembles *G. rapanui* (Greenfield and Hensley, 1970) which is endemic to Easter Island. Both species are elongate (depth 2.3–3.0 in SL), possess elongate posterior dorsal and anal rays and are predominately blackish in colouration with blue fin margins. *G. rapanui* differs by having biserial dentition, a slightly deeper body (average depth 2.7 in SL), and a colour pattern which includes blue spots on the head and anterior portion of the body, a pale caudal fin and peduncle, and a black spot covering the base of the pectoral fin. The counts for the fin rays, tubed lateral line scales and gill rakers are virtually identical in these two species.

G. notialis is one of the most common damselfishes outside the lagoon at Lord Howe Island. The habitat, which is essentially subtropical, consists largely of rocky canyons, ledges and boulders covered with algae. The species was observed at depths ranging from 7 to 45 metres. *G. rapanui* was observed by the author to inhabit a similar environment at Easter Island. The stomach contents of several paratypes of *G. notialis* contained algae and crustacean remains (largely copepods).

This species is named *notialis* (*Gr.* "southern") in reference to its geographical distribution. It is the most southerly occurring species of *Glyphidodontops* and a common inhabitant of Lord Howe Island, the world's southernmost coral reef.

Glyphidodontops talboti, n. sp.

(Plate III, Fig. c)

Holotype. AMS I.15684-004, 39.8 mm SL, coll. F. Talbot and party, 1/XII/1969, One Tree Island (23°30'S, 152°05'E), Capricorn Group, Great Barrier Reef, 30 m, explosives.

Paratypes. GREAT BARRIER REEF: AMS I.15486-038, 34.2 mm SL coll. H. Choat, 31/I/1966, Heron Island, Capricorn Group, 9 m, rotenone; AMS, I.16479-001, 39.7 mm SL, coll. W. Starck, 1/VII/1972, Pixie Reef, off Cairns, Queensland, 12 m, multi-prong spear; AMS I.15647-001, 36.5 mm SL, same data as holotype except coll. 9/X/1968, 13.5 m; AMS I.15637-009, 31.8 mm

SL, same data as holotype except coll. 5/X/1967, 23 m; INDONESIA : USNM 209745, 2 specimens, 22.7 and 34.7 mm SL, coll. V. Springer and M. Gomon, 11/I/1973, off Tandjung Suli, Ambon Island, Moluccas, 2-3 m, rotenone; USNM 210026, 2 specimens, 32.3 and 36.5 mm SL, coll. V. Springer and M. Gomon, 19/I/1973, offshore west of Tandjung Namatatuni, Ceram, Moluccas, 14-16 m, rotenone; SOLOMON ISLANDS : AMS I.17479-002, 38.8 mm SL, coll. G. Allen, 5/VII/1973, off Tassafaronga Point, about 7 nautical miles west of Honiara, Guadalcanal, 20 m, quinaldine; BMNH 1973.10.17.10-12, 3 specimens, 32.5-42.0 mm SL, coll. J. Randall and B. Goldman, 18/VII/1973, off southwest corner of Savo Island, 10 m, rotenone; MNHN 1973-60, 30.8 mm SL, coll. G. Allen and J. Randall, 30/VII/1973, off Tanavulu Point, northern end of Florida Island, 20-30 m, rotenone; NEW HEBRIDES : AMS I.17472-001, 3 specimens, 28.5-38.2 mm SL, coll. G. Allen, 22/VI/1973, off Malapoa Point, near Vila, Efate, 10 m, rotenone; AMS I.17473-001, 25.7 mm SL, coll. G. Allen and D. Popper, 23/VI/1973, about 3½ nautical miles south of Vila, Efate, 13 m, rotenone; AMS I.17475-001, 39.8 mm SL, coll. G. Allen, D. Popper and W. Starck, 25/VI/1973, Pula Iwa Reef (17°02'S, 168°17'E) off Emae Island, 25 m, rotenone; FIJI ISLANDS : AMS I.17464-001, 36.8 mm SL, coll. G. Allen, 8/VI/1973, outer reef at mouth of Nukulau Pass, near Suva, Viti Levu, 30 m, multi-prong spear; BPBM 14564, 37.0 mm SL, coll. J. Randall, 11/III/1973, outside Mbengga barrier reef, off Yanutha Island, 10 m, rotenone.

TABLE 5

Measurements of the holotype and two paratypes of Glyphidodontops talboti
(expressed in thousandths of the standard length)

Characters	Holotype	Paratype	Paratype
	AMS I.15684-004	AMS I.15647-001	AMS I.15637-009
Standard length (mm) ..	39.8	36.5	31.8
Greatest body depth ..	445	460	459
Greatest body width ..	190	209	203
Head length ..	299	315	315
Snout length ..	75	66	66
Eye diameter ..	108	115	132
Interorbital width ..	73	71	76
Least depth of caudal peduncle	151	145	148
Length of caudal peduncle ..	111	134	129
Snout to origin of dorsal fin ..	392	419	393
Snout to origin of anal fin ..	673	669	670
Snout to origin of pelvic fin	387	411	409
Length of dorsal fin base ..	575	597	576
Length of anal fin base ..	211	211	226
Length of pectoral fin ..	299	329	280
Length of pelvic fin ..	324	321	305
Length of pelvic spine ..	176	197	204
Length of 1st dorsal spine ..	58	74	60
Length of 8th dorsal spine ..	138	153	154
Length of last dorsal spine ..	91	93	91
Length of longest soft dorsal ray ..	216	214	186
Length of 1st anal spine ..	50	58	66
Length of 2nd anal spine ..	151	181	182
Length of longest soft anal ray	219	216	208
Length of middle caudal rays	302	329	320

Diagnosis. A species of *Glyphidodontops* with the following combination of characters: dorsal spines 13; horizontal scale rows between middle of lateral line and dorsal fin base 1½; predorsal scales reaching level of nostrils; suborbital and inferior limb of preopercle scaly; teeth biserial; membranes between dorsal

spines deeply to moderately incised; colour largely pale purple (red-brown in preservative) with prominent black spot near base of hindmost dorsal spines.

Description. Proportional measurements for the holotype and two selected paratypes are expressed as percentage of the standard length in Table 5.

Dorsal rays XIII, $11\frac{1}{2}$ (XIII, 11 to $11\frac{1}{2}$); anal rays II, 12 (II, $11\frac{1}{2}$ to 13) pectoral rays 16 (15 to 16); pelvic rays I, 5; branched caudal rays 13; gill rakers on the first arch 19 (18 to 20); tubed lateral line scales 16 (14 to 16); vertical scale rows from upper edge of gill opening to base of caudal fin 27; horizontal scale rows from base of dorsal fin to terminal lateral line scale (exclusive of dorsal base sheath scales) $1\frac{1}{2}$; from lateral line to anal fin origin 9; predorsal scales about 17 (17 to 20), extending to level of nostrils; teeth of jaws biserial, at least anteriorly, those in outer row somewhat spatulate with rounded tips, about 34 in lower jaw and 38 in upper jaw; teeth of inner row slender, about $\frac{1}{2}$ width or less of outer row teeth.

Body ovate, laterally compressed, the greatest depth 2.2 (2.2 to 2.3) in the standard length. Head profile conical, the head length contained 3.3 (3.2 to 3.3) times in the standard length; snout 4.0 (4.3 to 5.5), eye diameter 2.8 (2.4 to 3.0), interorbital width 4.1 (4.0 to 4.6), least depth of caudal peduncle 2.0 (1.8 to 2.2), length of caudal peduncle 2.7 (2.2 to 2.5), of pectoral fin 1.0 (1.0 to 1.2), of pelvic fin 0.9 (1.0 to 1.1), of middle caudal rays 1.0 (1.0 to 1.1), all in the head length.

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating $1\frac{1}{2}$ scale rows below base of last dorsal spine; suborbital scaled; snout tip, lips, chin, isthmus, and most of preorbital naked; remainder of head and body scaled; scales finely ctenoid; preopercle scale rows 2 with additional row of scales on inferior limb; small sheath scales covering about basal $\frac{1}{2}$ to $\frac{1}{3}$ of membranous portion of dorsal, anal, and caudal fins; margin of preorbital, suborbital, and bones of opercle series entire (edge of preopercle weakly crenulate in some specimens).

Origin of dorsal fin at level of fourth tubed lateral line scale; spines of dorsal fin gradually increasing in length to about eighth spine, remaining spines gradually decreasing in length; length of first dorsal spine 5.2 (4.3 to 5.8), of eighth dorsal spine 2.2 (1.9 to 2.2), of last dorsal spine 3.3 (2.8 to 3.4), of longest soft dorsal ray 1.4 (1.5 to 1.8), of first anal spine 6.0 (3.8 to 5.5), of second anal spine 2.0 (1.7 to 1.9), of longest soft anal ray 1.4 (1.4 to 1.7), all in the head length; caudal fin emarginate; pectoral fins pointed.

Colour of holotype in alcohol: Head and body generally reddish-brown; predorsal region, side of head and ventral surface of body suffused with yellow to tan; prominent black spot about size of eye near base of hindmost dorsal spines (9th to 13th), extending about halfway out on fin; anal papilla black; fins pale, slightly yellowish.

The 31.8 mm paratype from One Tree Island is faded due to the action of the preservative and is basically pale tan with the black dorsal spot and black anal papilla. The other paratypes from Melanesia and Queensland are similar to the holotype in colouration.

Colour in life: Most of body faded purple; predorsal region and head yellow; prominent black spot about 1– $1\frac{1}{2}$ size of eye at base of hindmost dorsal spines; anal papilla black; dorsal and anal fins usually translucent, yellow basally; pectoral and caudal fins translucent to pale yellow; pelvic fins yellow.

Remarks. *G. talboti* is closely related to *G. traceyi* from the Marshall and Caroline Islands. Morphologically the two species are nearly identical, but they differ significantly in colouration. The colour of several *G. traceyi* observed at Palau was as follows: head and body mostly purple grading to yellow at level of soft dorsal fin origin; anterior half of anal fin and spinous dorsal fin purple with black spot about size of eye at base of hindmost dorsal spines; soft dorsal fin,

caudal fin, and posterior half of anal fin yellow; pectoral fins translucent, pelvic fins dark purplish-brown. Thus, the colour pattern of *G. traceyi* is nearly the opposite of that exhibited by *G. talboti*, which is primarily yellow anteriorly and purplish posteriorly. Two specimens of *G. traceyi* which I collected at Palau also differ in having $10\frac{1}{2}$ soft dorsal rays, one less than the usual number for *G. talboti*. However, Woods and Schultz (1960) gave a range of 10 to 12 rays for 12 specimens from the Marshall Islands. They included *traceyi* in the genus *Pomacentrus* on the basis of the finely serrate preopercle. However, they stated that the serrations are so small they may be seen only with difficulty unless magnified and some specimens have the serrations only near the angle of the preopercle. Likewise, some specimens of *G. talboti* exhibit a weakly crenulate preopercle margin, usually confined to that portion near the angle. Examination of the general morphology of these species indicates a relationship to the genus *Glyphidodontops* rather than *Pomacentrus*. *G. rollandi* from the Indo-Australian Archipelago is a closely related form. *G. talboti* and *G. traceyi* appear to have allopatric distributions. The latter species is known from the Marshall and Caroline Islands and probably occurs at the Philippines. *G. talboti* is apparently confined to Indonesia, Melanesia and Queensland. In addition to the localities listed for the types, it was observed at Madang, New Guinea, at Rabaul, New Britain, at Egum Atoll (Solomon Sea), at the D'Entrecasteaux Islands and at Osprey Reef (Coral Sea).

Abudefduf bonang (non Bleeker) of Fowler and Bean (1928) is probably synonymous with *G. traceyi* judging from their description of specimens from the Philippines. The counts, measurements, size range (35–53 mm SL) and general colour pattern are in agreement. Bleeker's (1853; 1877) description and figure of *Paraglyphidodon bonang* indicate that it is a distinct species, differing from *G. traceyi* and *G. talboti* in several respects. The counts given by Bleeker which include 15 to 16 dorsal rays, 13 to 14 anal rays and 19 to 20 pectoral rays, represent significant differences. In addition, *P. bonang* grows to a much larger size. The largest specimen recorded by Bleeker was 150 mm TL, nearly three times the length of the author's largest *G. talboti*. The author has observed hundreds of individuals of *G. traceyi* and *G. talboti* in the sea, none of which exceeded about 60 mm TL. The 36.5 mm SL paratype of *G. talboti* is a mature female with eggs, also indicative of the small size of the species. Specimens of *P. bonang* were reported by Bleeker (1877) and de Beaufort (1940) as having a white-edged dark brown ocellus near the middle of the dorsal fin. According to Bleeker, this ocellus may disappear in large specimens. *G. traceyi* and *G. talboti*, by contrast, do not have a pale ring around the dark dorsal spot and the spot persists in individuals of all sizes.

The status of *Glyphidodon mutabilis* Cartier (1874), relegated to a synonym of *Abudefduf bonang* (non Bleeker) by Fowler and Bean (1928) is uncertain. The soft dorsal and anal fin ray counts are too high for either *G. traceyi* or *G. talboti*.

G. talboti was generally observed on outer reef slopes in depths ranging from about 8 to 30 metres. It is a solitary dweller which hovers a short distance above the bottom while feeding. The stomach contents of two paratypes indicate a diet consisting largely of pelagic tunicates, copepods, isopods and a small amount of algae.

Named in honour of Dr. Frank H. Talbot, Director of the Australian Museum, the collector of the holotype.

Pomacentrus albimaculus, n. sp.

(Plate IV, Figs. a and b)

Holotype. AMS I.16691-006, 61.7 mm SL, coll. G. Allen, 7/IV/1972, near main wharf at Madang, New Guinea (5°14'S, 145° 45'E), 16 m, multi-prong spear.

Paratypes. AMS I.16691-007, 3 specimens, 45.5–56.5 mm SL, collected with the holotype.

Diagnosis. A species of *Pomacentrus* with the following combination of characters: body depth 1.9 to 2.0 in SL; dorsal spines 13; preorbital and suborbital naked; prominent notch between preorbital and suborbital; inferior edge of suborbital denticulate; teeth biserial anteriorly; colour grey (brown in preservative) with darker scale edges giving overall reticulated appearance, prominent white spot on upper half of caudal peduncle when alive.

Description. Proportional measurements for the holotype and two selected paratypes are expressed as percentage of the standard length in Table 6.

Dorsal rays XIII, 14½; anal rays II, 15½ (II, 14½ to 15½); pectoral rays 17; pelvic rays I, 5; branched caudal rays 13; gill rakers on the first arch 21 (20 to 21); tubed lateral line scales 17 (16); vertical scale rows from upper edge of gill opening to base of caudal fin 28; horizontal scale rows from base of dorsal fin to terminal lateral line scale (exclusive of dorsal base sheath scales) 1½; from lateral line to anal fin origin 9; predorsal scales about 18, extending to level of nostrils; teeth conical with rounded tips, biserial at front of jaw, about 34 primary teeth in the lower jaw and 40 in the upper.

TABLE 6
Measurements of the holotype and two paratypes of Pomacentrus albimaculus
(expressed in thousandths of the standard length)

Characters	Holotype	Paratype	Paratype
	AMS I.16691-006	AMS I.16691-007	AMS I.16691-007
Standard length (mm)	61.7	56.5	45.5
Greatest body depth	519	492	517
Greatest body width	195	188	198
Head length	300	301	306
Snout length	75	81	75
Eye diameter	97	96	106
Interorbital width	73	78	84
Least depth of caudal peduncle	146	149	143
Length of caudal peduncle ..	97	94	88
Snout to origin of dorsal fin ..	381	372	374
Snout to origin of anal fin ..	622	639	666
Snout to origin of pelvic fin ..	376	372	391
Length of dorsal fin base ..	674	646	633
Length of anal fin base ..	327	303	286
Length of pectoral fin ..	292	294	297
Length of pelvic fin	324	324	328
Length of pelvic spine ..	175	184	199
Length of 1st dorsal spine ..	86	71	88
Length of 7th dorsal spine ..	154	154	171
Length of last dorsal spine ..	173	168	185
Length of longest soft dorsal ray	259	258	286
Length of 1st anal spine ..	73	73	73
Length of 2nd anal spine ..	165	161	174
Length of longest soft anal ray	256	264	259
Length of middle caudal rays	248	265	275

Body ovate, laterally compressed, the greatest depth 1.9 (1.9 to 2.0) in the standard length. Head profile conical, the head length contained 3.3 times in the standard length; snout 4.9 (3.7 to 4.1), eye diameter 3.1 (2.9 to 3.1); interorbital width 4.1 (3.7 to 3.9), least depth of caudal peduncle 2.1 (2.0 to 2.1), length of caudal peduncle 3.1 (3.2 to 3.5), of pectoral fin 1.0, of pelvic fin 0.9, of middle caudal rays 1.2 (1.1), all in the head length.

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating 1½ scale rows below base of second soft dorsal ray; preorbital, suborbital, snout tip, lips, chin, and isthmus naked; remainder of head and body scaled; scales finely ctenoid;

preopercle scale rows 3; small sheath scales covering basal $1/2$ to $2/3$ of mem-
braneous portions of dorsal, anal, and caudal fins; margin of preorbital, suborbital-
and preopercle denticulate; margin of opercle entire.

Origin of dorsal fin at level of third tubed lateral line scale; spines of dorsal
fin gradually increasing in length to last spine; length of first dorsal spine 3.5
(3.5 to 4.3); of seventh dorsal spine 1.9 (1.8 to 2.0); of last dorsal spine 1.7
(1.7 to 1.8); of longest soft dorsal ray 1.2 (1.1 to 1.2); of first anal spine 4.1
(4.1 to 4.2), of second anal spine 1.8 (1.8 to 1.9), of longest soft anal ray 1.1 (1.1
to 1.2), all in the head length; caudal fin slightly emarginate; pectoral fins
pointed.

Colour of holotype in alcohol: Head and body brown, scale margins and top
of head darker; upper portion of caudal peduncle pale tan; dorsal and anal fins
brownish with one or two pale submarginal bands, distal tips of membranes
between dorsal spines black and small dark spot in middle of soft dorsal between
9th and 11th ray; caudal fin brown; pectoral and pelvic fins pale tan; small
blackish spot on opercle near lateral line origin and diffuse dark spot on upper
pectoral base, axil of pectoral pale.

Colour of holotype in life: Head and body grey with dusky scale edges
giving overall reticulated appearance; median fins pale grey with one or two
pale blue submarginal bands on dorsal and anal fins; pelvic fins pale blue-grey;
pectoral fin translucent with blackish spot at upper portion of fin base; small
bluish spot on opercle near origin of lateral line; prominent white spot on upper
half of caudal peduncle.

The small dark spot between the 9th and 11th soft dorsal rays is a remnant
of the juvenile ocellus which disappears with growth. The ocellus is generally
present on specimens under about 40 mm SL.

Remarks. *P. albimaculus* belongs to the subgenus *Pseudopomacentrus*
Bleeker and is closely allied to the following species from the western Pacific:
P. amboinensis Bleeker, *P. grammorhynchus* Fowler, *P. melanochir* Bleeker, *P.*
melanopterus Bleeker, *P. moluccensis* Bleeker, *P. nigromanus* Weber, *P. nigro-*
marginatus Allen, *P. philippinus* Evermann and Seale, and *P. tripunctatus* Cuvier
and Valenciennes. The relationships between most of the members of this
group have been discussed by Allen (1973). *P. albimaculus* appears to be most
closely related to *P. amboinensis*, but this latter species differs by having a slightly
higher gill raker count (22 to 24), and is primarily yellowish in colouration. *P.*
nigromarginatus has a similar reticulated pattern and grey ground colour, but
differs by having a black margin on the soft dorsal and caudal fins, an intense
black spot covering the entire pectoral fin base and axil, and usually 14 or 15
tubed lateral line scales.

P. albimaculus was only encountered at Madang during a cruise which
included several stops along the northeastern coast of New Guinea from Madang
to Samarai. It was relatively common in the harbour and lagoon in turbid areas
of limited visibility at depths between 10 and 20 metres. It shares this habitat
with *P. amboinensis*. The stomach contents of the holotype consisted mainly
of algae.

The specific name *albimaculus* refers to the characteristic white spot on the
upper caudal peduncle.

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Fig. a. *Glyphidodontops niger*, holotype, 41.8 mm SL, Cape Nelson, New Guinea.

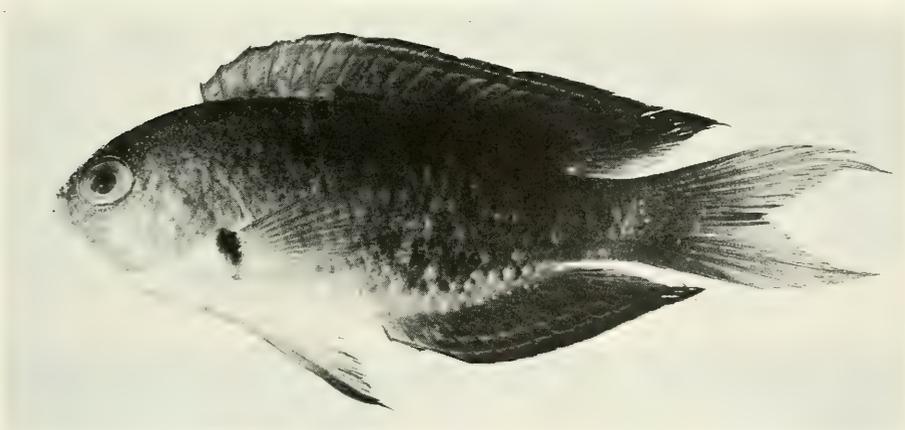


Fig. b. *Glyphidodontops notialis*, holotype, 49.2 mm SL, Lord Howe Island.

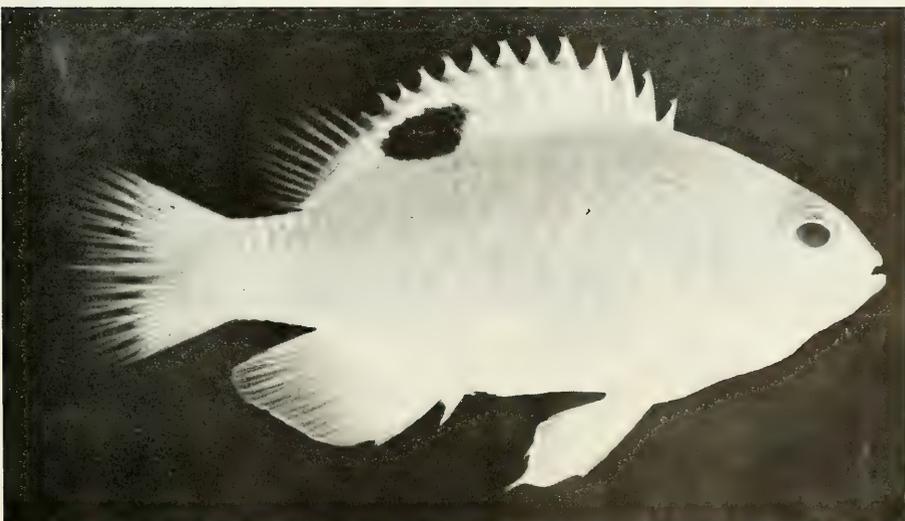


Fig. c. *Glyphidodontops talboti*, paratype, 37.0 mm SL, Fiji Islands.

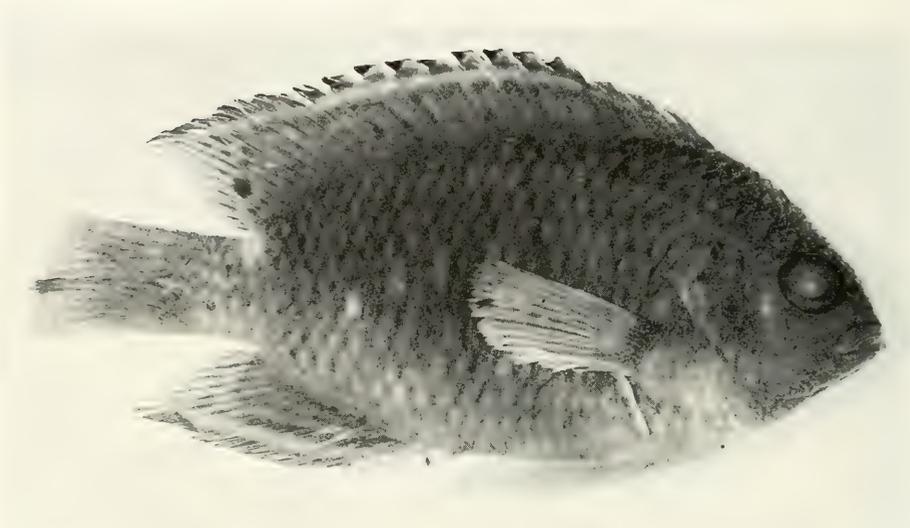


Fig. a. *Pomacentrus albimaculus*, holotype, 61.7 mm SL, Madang, New Guinea.

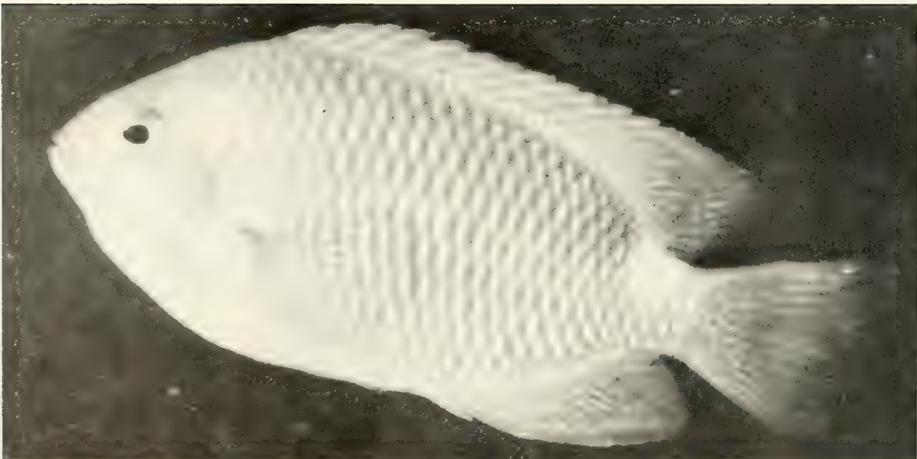


Fig. b. *Pomacentrus albimaculus*, approximately 70 mm SL, underwater flash photograph taken at Madang, New Guinea, near the type locality.

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POWDERY MILDEW ON CUCURBITACEAE: IDENTITY, DISTRIBUTION, HOST RANGE AND SOURCES OF RESISTANCE

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Synopsis

The species of powdery mildew fungi recorded on cucurbits are reviewed and the value of several characteristics of the imperfect stage in distinguishing these species in the absence of the perithecia is considered. One hundred and fifty collections were made in New South Wales from a wide area and climatic range and on numerous commonly grown species, cultivars and plant introductions of *Citrullus*, *Cucumis* and *Cucurbita*. All field collections resembled the imperfect stage of *Sphaerotheca fuliginea* in having conidia which are borne in chains, have well-developed fibrosin bodies and which produce germ tubes, some of which are forked. These characters have occurred consistently in mildews identified as *S. fuliginea* on the basis of perithecial characteristics by several workers in several countries.

Before 1958 *Erysiphe cichoracearum* had generally been assumed to be the most common and widespread powdery mildew species on Cucurbitaceae, but recent reports and results of this investigation now indicate that a mildew resembling the imperfect stage of *S. fuliginea* is generally the more important species.

Cucurbita lundelliana and numerous cultivars and plant introductions of *Cucumis melo* and *C. sativus*, which have previously been reported to have resistance to a mildew referred to as *Erysiphe cichoracearum* in the U.S.A. and in other countries, were found to have resistance to the powdery mildew in New South Wales.

A list has been made of cultivars and plant introductions of *Cucumis melo*, *C. sativus* and *Cucurbita* spp. which have shown resistance and which are suitable for commercial production or use in breeding programmes.

INTRODUCTION

Six species of powdery mildew fungi are recorded on Cucurbitaceae in various parts of the world: *Erysiphe cichoracearum* DC. ex Mérat, *E. communis* (Wallr.) Link., *E. polygoni* (DC.) St.-Am., *E. polyphaga* Hammarlund, *Leveillula taurica* (Lev.) Arnaud and *Sphaerotheca fuliginea* (Schlecht. ex. Fr) Poll. There are also records of conidial powdery mildew fungi as *Oidium* sp. More than one species may occur in the same locality (Teterevnikova-Babayan and Simonyan, 1956) and on the same plant (Deckenbach and Koreneff, 1927).

The two species most commonly recorded are *E. cichoracearum* and *S. fuliginea* but, since they rarely produce perithecia on cucurbits and their imperfect forms have many similar features, the validity of most published records based on the conidial stage requires confirmation.

In the U.S.A. resistance of cultivars and plant introductions was specifically claimed to be to *E. cichoracearum*. No mention has been made of resistance to *S. fuliginea*. However, Bohn and Whitaker (1961) stated that 'it seems desirable that studies designed to determine the true identity or identities of *Oidium* stages of Erysiphaceae on cucurbits should be made.' They drew attention to the conflicting host range reports in the literature, the demonstration of strains with different temperature requirements which 'suggested that the relationships need clarification.'

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In New South Wales powdery mildew is common on rockmelon (muskmelon) (*Cucumis melo* L.), cucumber (*C. sativus* L.) pumpkin (*Cucurbita maxima* Duch.), marrow (*C. pepo* L.) and other related plants (Noble *et al.*, 1934). The fungus was referred to as *E. cichoracearum* in earlier publications, but more recently has been termed *Oidium* sp. (Anon., 1959), as only the imperfect stage has been collected.

In the late 1950's the most widely grown rockmelon cultivar, Powdery Mildew Resistant No. 45 (PMR 45), became severely affected by powdery mildew in the south western areas of the State (Anon., 1959). The cultivars PMR Nos. 5 and 6 were resistant in 1959 but were severely affected the next season in the same districts (Anon., 1960). The conidia of all collections of the fungus on PMR Nos. 5, 6 and 45 contained well-developed fibrosin bodies (Zopf, 1887; Blumer, 1933; Homma, 1937; Clare, 1958), which may be used as a characteristic for distinguishing *Erysiphe* and *Sphaerotheca*. Their presence suggested that the fungus was the imperfect stage of *S. fuliginea* and not *E. cichoracearum*.

A survey of powdery mildews on Cucurbitaceae in New South Wales was therefore carried out from 1963 to 1965 to determine the species present and to compare the disease reaction of cultivars and breeding lines grown both here and in other countries.

THE FUNGI—TAXONOMY

Perithecia

Six species of powdery mildews have been recorded on cucurbits in the perithecial stage. Most records are of *E. cichoracearum* and *S. fuliginea* and their distributions are given in Tables 1 and 2. *Erysiphe polygoni* was recorded on *Cucurbita pepo* in Poland by Schroeter (1893) and in Japan on three uncommon species by Homma (1937).

There are several records of perithecia of powdery mildews on cucurbits under the names *E. communis* and *E. polyphaga* (Berlese and Peglion, 1892; Hammarlund, 1945; Blumer, 1952). Both the taxonomy and nomenclature of these two fungi need further study (Junell, 1965; 1967). The records of *E. cichoracearum* in Table 1 include those of *E. polyphaga*.

Leveillula taurica was listed, together with *E. cichoracearum* and *S. fuliginea* on cucurbits in the U.S.S.R. by Gordeeva (1961) and by Tarr (1955) with *S. fuliginea* in the Sudan. Golovin (1956) refers to *Leveillula* on *Cucurbitaceae* in her detailed survey of the genus, in which she split *L. taurica* into species for each host family. She described *L. cucurbitarum* on cucumber, marrow and *Cucurbita* sp. in the U.S.S.R. but the description is invalid as no Latin diagnosis is given.

Imperfect Stage: Taxonomic Value of Characters of the Imperfect Stage in distinguishing Powdery Mildew Species

As the identification of genera of powdery mildew is based primarily on characters of the perithecia which are not always developed, the definition of characteristics which could be used for precise identification in the absence of the perfect stage would be of great value. Length and structure of conidiophores, presence or absence of well-developed fibrosin bodies in conidia, and the morphology of the germ tubes and appressoria, all appear to be suitable characteristics (Ballantyne, 1963; Clare, 1964). The presence or absence of mycelial appressoria and hyphal swellings also provide useful characters for distinguishing species.

Leveillula taurica is easily distinguished from other powdery mildews on cucurbits in having internal mycelium and *Oidiopsis*-type conidiophores. *E. polygoni* is the only mildew with a single matured spore at the end of the conidio-

TABLE 1
Records of perithecia of *Erysiphe cichoracearum* on Cucurbitaceae

Country	Reference	Remarks
AFRICA		
No records		
ASIA		
India	Butler and Bisby, 1931	On <i>Momordica balsamina</i> and <i>Trichosanthes dioeca</i> .
"	Rajendrau, 1965	On <i>Lagenaria vulgaris</i> .
"	Khan <i>et al.</i> , 1972	On <i>Coccinia cordifolia</i> .
Malaysia and Singapore	Thompson, 1933	On pumpkin.
AUSTRALASIA		
No records		
EUROPE		
Surrey, England	Salmon, 1900	On <i>Cucurbita pepo</i> .
France	Viennot-Bourgin, 1956	On <i>Cucumis melo</i> and <i>C. sativus</i> .
Berlin, Germany	Roder, 1937	On <i>Cucumis sativus</i> .
Sweden	Junell, 1967	Four of ten collections on <i>Cucumis sativus</i> and <i>Cucurbita pepo</i> showed perithecia.
NORTH AMERICA		
Nova Scotia, Canada	Herbarium spec. 1798c. Dominion Laboratory of Plant Pathology, Coll. D. Creelman 1951	On <i>Cucumis sativus</i> .
Massachusetts, U.S.A.	Humphries, 1893	In a greenhouse.
Washington State, U.S.A.	Randall and Menzies, 1956	Perithecia on two <i>Cucumis</i> introductions U.S.P.I. 179260 and 181910 after a light frost.
Wisconsin, U.S.A.	Reed, 1908	Perithecia were on squash, pumpkin and cucumber cotyledons in a greenhouse.
SOUTH AMERICA		
No records		
U.S.S.R.*		
†Armenia	Teterevnikova-Babayan and Simonyan, 1956	Perithecia commonly occurred in the lowlands but not in the mountains.
†Crimea	Deckenbach, 1924	Perithecia of <i>Sphaerotheca fuliginea</i> were predominant on squashes and marrows. <i>E. cichoracearum</i> was not recorded on melon.
† "	Deckenbach and Koreneff, 1927	Perithecia of <i>E. cichoracearum</i> occurred on the upper surfaces and <i>S. fuliginea</i> on the lower surface of <i>Cucumis melo</i> .
†Volga Basin	Rodigin, 1936	On unspecified cucurbits.

* Because of the difficulty in accurately placing some U.S.S.R. records in either Europe or Asia, a separate category was used.
† Indicates records where perithecia of *E. cichoracearum* and *S. fuliginea* occur together.

TABLE 2
Records of perithecia of *Sphaerotheca fuliginea* on *Cucurbitaceae*

Country	Reference	Remarks
AFRICA		
Republic of Sudan	Tarr, 1955	Perithecia collected on three occasions on <i>Cucurbita pepo</i> .
"	Nour, 1959	On <i>Cucurbita pepo</i> .
ASIA		
India	Butler and Bisby, 1931	On <i>Lagenaria vulgaris</i> and <i>Cucurbita moschata</i> .
"	Sohi and Nayar, 1969	On <i>Cucurbita moschata</i> .
"	Khan and Khan, 1970	On certain cultivars of <i>Cucumis sativus</i> and <i>Lagenaria leucantha</i> .
"	Khan <i>et al.</i> , 1972	On <i>Cucurbita maxima</i> and <i>Lagenaria leucantha</i> .
Israel	Rayss, 1947	On <i>Cucumis sativus</i> and <i>Cucurbita pepo</i> .
Japan	Homma, 1937	On <i>Cucurbita moschata</i> var. <i>toonias</i> .
"	Uozumi and Yoshii, 1952	Perithecia were common in late autumn in Fukioka but were uncommon elsewhere.
Taiwan	Hashioka, 1937	Perithecia formed in winter in the laboratory.
"	Sawada, 1959	On <i>Cucurbita maxima</i> and <i>C. moschata</i> var. <i>toonias</i> .
AUSTRALASIA		
New Zealand	Dingley, 1959	On <i>Cucurbita pepo</i> .
EUROPE		
Greece	Zaracovitis, personal communication	The perithecia are commonly formed.
"	Pantidou, 1971	On <i>Cucumis sativus</i> and <i>Cucurbita pepo</i> .
Hungary	Nagy, 1970	On <i>Cucumis melo</i> .
Turin, Italy	Blumer, 1933	On <i>Cucurbita pepo</i> .
Herastrau, Romania	Savalescu, Tr. 1929	On <i>Cucurbita pepo</i> .
People's Republic	Herbarium mycologicum Romanium Exsiccata	
	Fasc. 1, No. 10,	
	Anon., 1965	
Wageningen, The Netherlands	Bremer <i>et al.</i> , 1947	On <i>Cucurbita pepo</i> , <i>Cucumis melo</i> and <i>Lagenaria vulgaris</i> .
Turkey		
NORTH AMERICA		
No records		
SOUTH AMERICA		
No records		
U.S.S.R.*		
†Armenia	Teterevnikova-Babayan and Simonyan, 1956	Perithecia commonly occurred in lowlands, but not in mountains.
Astrakhan	Szembel, 1926	On melon.
Caucasus	Poretzky, 1923	On melon, <i>Cucumis melo</i> .
†Crimea	Deckenbach, 1924	Perithecia on <i>S. fuliginea</i> were predominant on squashes, marrows and melons.
†	Deckenbach and Koreneff, 1927	Perithecia of <i>Erysiphe cichoracearum</i> occurred on the upper surface and <i>S. fuliginea</i> on the lower surface of <i>Cucumis melo</i> .
Southern Russia	Jaczewski, 1904	On pumpkin. Perithecia were extremely rare.
†Volga Basin	Rodigin, 1936	On unspecified cucurbits.

* Because of the difficulty in accurately placing some U.S.S.R. records in either Europe or Asia, a separate category was used.
† Indicates records where perithecia of *E. cichoracearum* and *S. fuliginea* occur together.

phore. The only confusion likely is between *E. cichoracearum* and *S. fuliginea* which both have external mycelium and *Oidium*-type conidiophores with long chains of conidia.

Fibrosin bodies were first reported by Zopf (1887) in the conidia and conidiophores of *Podosphaera oxycanthae*. Foex (1912, 1925) and Bouwens (1927) considered that they were of value in distinguishing certain species and described them in more detail. Blumer (1933) considered that presence or absence of fibrosin bodies was probably of some value in distinguishing the oidial stages of *E. cichoracearum* and *S. fuliginea* on cucurbits. This was confirmed by Homma (1937) who described two forms, a granular form characteristic of *Erysiphe* and a form characteristic of *Sphaerotheca* which is either cylindrical or disc-, cone-, or truncated-cone shaped.

Clare (1958, 1964) recognised the significance of well-developed fibrosin bodies and used their presence or absence in distinguishing mildews on cucurbits and other hosts in south eastern Queensland. Several workers, including Uozumi and Yoshii (1952), Hashioka (1937), Sawada (1959), Dingley (1959) and personal communication and Nagy (1970), either describe or figure well-developed fibrosin bodies in cucurbit powdery mildews identified on perithecial characters as *S. fuliginea* from Japan, Taiwan, New Zealand, The Netherlands and Hungary respectively. Ellert (1966) reported that these structures were present in powdery mildews identified as *S. fuliginea* from perithecia on non-cucurbitaceous hosts.

Klika (1922) reported fibrosin bodies in numerous species including *E. cichoracearum*, *E. polygوني* and *S. humuli* but without specifying the type.

The shape of the germ tube was claimed to be characteristic of the species of powdery mildew by Hirata (1942, 1955) and later by Zaracovitis (1965). The germ tubes of *E. cichoracearum* were simple with inconspicuous appressoria, those of *E. polygوني* formed complex appressoria, and some but not all of the germ tubes of *S. fuliginea* were forked. Hashioka (1937), Boerema and Van Kesteren (1964) and Nagy (1970) reported forking of the germ tubes of *S. fuliginea* on cucurbits in Taiwan, The Netherlands and Hungary. Homma (1937) and Salmon (1900) figure the many-lobed appressoria of *E. polygوني* on other hosts.

Conidia of *E. cichoracearum*, *E. polygوني* and *S. fuliginea* have generally similar shape and size. However, some workers (Bouwens, 1924; Yarwood, 1957 and Nagy, 1970) consider that measurements of length and breadth are of value in distinguishing between these species. Details of conidial measurements recorded by other workers on cucurbits are given by Ballantyne (1971).

A species of *Oidium* resembling the imperfect stage of *S. fuliginea* in having long chains of conidia, well-developed fibrosin bodies and a proportion of forked germ tubes, has been recorded throughout Australia and in several overseas countries (Table 3). Only two records of an imperfect stage lacking well-developed fibrosin bodies and resembling *E. cichoracearum* in other ways have been reported. These were on *Momordica charantia* L. and *Sechium edule* Sw. in Hawaii (Raabe, 1966) and on several cucurbits in Hungary, where it occurred with *S. fuliginea* which was identified on perithecial characteristics (Nagy, 1970).

THE HOSTS

Powdery mildew is a serious disease of susceptible rockmelon cultivars in many countries, particularly in arid areas where large scale commercial production often takes place. It is usually less severe on pumpkins, marrows, squashes and cucumbers, although it can be a serious problem in glasshouse cucumbers in Europe, mainly because of continuous culture and very favourable conditions for development of the disease. Watermelon (*Citrullus lanatus* (Thunb.) Mansfeld var. *caffer* Mansfeld) is not often affected, but occasional severe outbreaks

occur. In New South Wales two common cucurbitaceous weeds, the prickly paddy melon (*Cucumis myriocarpus* Naud.) and the wild watermelon or camel melon (*Citrullus lanatus* var. *lanatus*) may also be affected.

Rockmelon

The primary gene centre of *Cucumis melo* is probably in tropical Africa, and well-developed secondary gene centres of cultivated melons are in India, Iran, southern U.S.S.R. and China.

Many powdery mildew resistant lines have been collected in Asia and Africa and extensive breeding for resistance has been carried out. Details are in the Appendix.

TABLE 3

Records of Oidium sp. resembling the imperfect stage of Sphaerotheca fuliginia

<i>Africa</i>					
South Africa	..	..	..	..	Gorter, 1966
<i>Asia</i>					
India	..	..	..	..	Jhooty, 1967
Israel	..	..	..	..	Rudich <i>et al.</i> , 1969
<i>Australasia</i>					
New South Wales, Australia	..	..	..	..	Ballantyne, 1963 ; Clare, 1964
Northern Territory, Australia	..	..	..	..	Ballantyne, unpublished data
Queensland, Australia	..	..	..	..	Clare, 1958, 1964
South Australia	..	..	..	..	Harrison, personal communication
Western Australia	..	..	..	..	McNish, 1967
<i>Europe</i>					
England	..	..	..	..	Zaracovitis, 1965
Greece	..	..	..	..	Zaracovitis, personal communication
The Netherlands	..	..	..	..	Boerema and Van Kesteren, 1964 Kooistra, 1968
<i>North America</i>					
California, U.S.A.	..	..	..	..	Yarwood and Gardiner, 1964 Paulus <i>et al.</i> , 1968 Bohn, personal communication
New York State, U.S.A.	..	..	..	..	Kable and Ballantyne, 1963 Schroeder and Provvidenti, 1968
Ohio, U.S.A.	..	..	..	..	Ellert, 1966
<i>South America</i>					
No records					

The most widely grown cultivar is Powdery Mildew Resistant No. 45 (PMR 45) which was released in California in 1936 (Jagger and Scott, 1937), and is still widely grown though it was affected by a new race (race 2) in 1938 (Jagger *et al.*, 1938*a*). It is reported to be resistant to at least some of the races of powdery mildew present in some of the Eastern States of the U.S.A. (Markarian and Harwood, 1967).

Five genes for powdery mildew resistance have been designated, Pm¹⁻⁵ (Jagger *et al.*, 1938*b* ; Whitaker and Pryor, 1942 ; Bohn, 1961 ; Bohn and Whitaker, 1964 ; Harwood and Markarian 1968*a* and *b*).

Cucumber

India is considered to have been the centre of origin of the cucumber (Leppik, 1966*b*). Many powdery mildew resistant collections have been made in India and Africa and some breeding for resistance has been carried out. Details are in the Appendix.

Inheritance of resistance has been shown to be complex (Smith, 1948 ; Kooistra, 1968 ; Shanmugasundaram *et al.*, 1971).

Cucurbita species

America, possibly Central America and southern Mexico is the centre of origin of the genus *Cucurbita* (Whitaker, 1956).

Powdery mildew resistance has been reported in *Cucurbita lundelliana* L. H. Bailey where it is controlled by a single dominant gene (Rhodes, 1959 ; 1964) and in *C. martinii* L. H. Bailey. Further details are in the Appendix.

Watermelon

The watermelon probably originated in tropical Africa (Whitaker and Davis, 1962). There are no published reports of varietal resistance to powdery mildew.

Many rockmelon and cucumber cultivars bred for resistance in one country also have resistance in other countries. Details are given in Table 4.

MATERIALS AND METHODS

One hundred and fifty collections of powdery mildew were made from a wide range of locations and climates and on numerous cucurbit species and cultivars.

The fungus was mounted in 3% aqueous potassium hydroxide for examination of fibrosin bodies and in tap water for examination of the conidiophore and measurement of 20 conidia.

Germ tubes were obtained by germinating conidia on strips of onion bulb epidermis according to the method of Hirata (personal communication). Epidermis was stripped from the adaxial surface of the swollen leaf base, immersed for three to five minutes in 80% ethanol and washed in running water for two hours. The strips were placed on a microscope slide with the cuticular surface uppermost and blotted to remove excess moisture. Conidia were dusted onto the strip and tap water was added with a dropper so that the strip floated. Early collections were checked only for presence or absence of forking, but as investigation proceeded the need for more precise data was recognised and the percentage of germ tubes showing forking in at least 500 germinating conidia was determined for later collections.

The specimens are filed in the Herbarium of the Biology Branch, Biological and Chemical Research Institute, Rydalmere (DAR). Permanent mounts of the germinated and fresh spores were not made as no method of preserving these in a satisfactory condition was known. Herbarium specimens of conidial powdery mildews deteriorate with age and whilst structures resembling fibrosin bodies were detected in herbarium specimens ten years old, they were faint and infrequent.

THE HOSTS

As considerable variation had previously been observed in the reaction to powdery mildew of commercial lines of powdery mildew-resistant rockmelon cultivars, seed of such cultivars was obtained from the original breeder wherever possible. Where commercial seed was used, lines of each resistant cultivar were obtained from two different seedsmen. Details of seed source are given by Ballantyne (1971).

During 1963, 53 lines of *Cucumis melo* were grown at Rydalmere near Sydney, New South Wales, in hills with eight plants of each line per hill. Where seed of some of the U.S. Plant Introductions was limited, no fewer than four plants of each line were grown.

TABLE 4
Powdery mildew reaction of cucumber and rockmelon cultivars in areas other than U.S.A. and New South Wales

Country	Fungus	References	Cultivars resistant
AFRICA			
Republic of Sudan	<i>S. fuliginea</i>	Tarr, 1952	Some unspecified resistant cultivars bred in the U.S.A. showed varying degrees of resistance.
South Africa	<i>Oidium</i> sp. resembling <i>S. fuliginea</i>	Smit, 1964 Gorter, 1966	Georgia 47 rockmelon (<i>Cucumis melo</i>). Imperial 45 rockmelon.
ASIA			
Israel	<i>Oidium</i> sp. resembling <i>S. fuliginea</i>	Rudich <i>et al.</i> , 1969	Several rockmelon cultivars bred from PMR 45, Seminole and Davis X sources of resistance were resistant in Israel until 1967 and then became moderately susceptible. The cultivar Jacumba remained unaffected.
Japan	<i>S. fuliginea</i>	Tamai <i>et al.</i> , 1962	Iyo I, a powdery mildew resistant rockmelon cultivar was selected from PMR 5 × Earl's Favourite.
AUSTRALASIA			
Victoria, Australia	<i>Oidium</i> sp. resembling <i>S. fuliginea</i>	Kefford <i>et al.</i> , 1958 Harrison, personal communication McNish, 1967	PMR 45, Rio Gold and Invader (syn. Georgia 47) resistant.
Western Australia			PMR 45, PMR 5, Rio Gold, Florigold and Florisun rockmelons, and Ashley, Stono and Palomar cucumbers.
EUROPE			
The Netherlands	<i>S. fuliginea</i>	Anon., 1965	Of several cucumbers, viz., Ashley and related cultivars, U.S.P.I. Nos. 200815 and 200818 which have resistance in the U.S.A., and Natsufushinari which has resistance in Japan, most had some resistance in The Netherlands.
Portugal	unknown	Mendonca and Rodriguez, 1966	PMR Nos. 5, 6, 45 and 88 rockmelons.
NORTH AMERICA			
Mexico	unknown	Munoz, 1965	Edisto rockmelon.
U.S.S.R.			
Bulgaria	<i>S. fuliginea</i>	Lozanov and Vitanov, 1970	Rockmelon cultivars Edisto and PMR 45 resistant and PMR 6 highly resistant.

During 1964, 36 lines of *C. melo*, and ten lines of *Cucurbita* species were grown. These lines included cultivars of *C. maxima*, *C. moschata* and *C. pepo*, the three *Cucurbita* species cultivated in New South Wales, and *C. lundelliana*.

In the 1963 season, the results were recorded as resistant or susceptible (except for one line) as the plants were either free from disease or severely affected.

In the 1964 season, disease ratings were recorded on the following scale and the time of fruit maturity noted. The results (Table 5) were recorded when the fruit first ripened.

R—Fully resistant ; no mildew seen.

R⁻—Resistant ; mildew on less than 5% of leaf surface.

MR—Moderately resistant ; mildew on 5–30% of the leaf surface.

S⁻—Susceptible ; mildew on more than 30% of leaf surface ; ripe fruit produced.

S—Fully susceptible ; mildew on more than 30% of leaf surface ; no ripe fruit produced.

Observations were also made on the powdery mildew reactions of various lines grown in small scale replicated and unreplicated trials at Griffith and Yanco in the Riverina district in the south west of New South Wales during 1964 and 1965 and at Rydalmere in 1966.

Limited cross-inoculation experiments were carried out by transferring mildew spores with a scalpel from french bean (*Phaseolus vulgaris* L.), cucumber, and noogoora burr (*Xanthium chinense* Mill.) on to rockmelon (cv. Bender's Surprise) plants raised under bell jars.

RESULTS

The fungi

The 150 collections on naturally-infected cucurbits from New South Wales showed conidial characteristics of *S. fuliginea*. The percentage of forking in 80 specimens varied between 5 and 60%, with most specimens in the range 3 to 5%. Seventy specimens were checked only for presence or absence of forking. The conidial measurements were (24) 27–40 × 16–24 (27) μm.

The host plants on which mildew collected included : *Citrullus lanatus* var. *lanatus*, wild watermelon ; *C. lanatus* var. *caffer*, watermelon, one cv. ; *Cucumis melo* subspecies *conomon* (Thunb.) Greb., oriental pickling melon, eight accessions ; *C. melo* subspecies *melo*, cultivated rockmelon, 17 cvs ; *C. melo* subspecies and cultivar unknown, three accessions ; *C. myriocarpus*, prickly paddy melon ; *C. sativus*, cucumber, 11 cvs ; *Cucurbita ficifolia* Bouché, fig leaf gourd ; *C. lundelliana*, the peten gourd ; *C. martinii* ; *C. maxima*, pumpkin and hubbard squash, 7 cvs ; *C. moschata* Duch. ex Poir, gramma, pumpkin and trombone, 2 cvs ; *C. palmata* Wats. ; *C. pepo*, marrow and squash, 5 cvs ; *C. radicans* Naud. ; *C. texana* A Gray ; *Cucurbita* spp. unknown and a gourd, genus and species unknown.

Most of the specimens were collected in February (78), March (24), January (22) and April (16), with less in May (5), June (3), July (1) and October (1). Ninety-four of the specimens were collected in the Sydney Metropolitan Area, 29 in the Riverina, 7 in the Central Tablelands, 4 in the North West Slopes, 5 in the Northern Tablelands, 3 each in the Manning and Central Coast area, 2 each in the Australian Capital Territory and on the North Coast and one in the North West Plains. One collection from the Northern Territory was examined. This specimen resembled those in the New South Wales area in having long chains of conidia, a similar size, well-developed fibrosin bodies and a proportion of forked germ tubes.

Both a collection from cucumber and a collection from french bean which resembled the cucurbit powdery mildew fungus, readily infected rockmelon plants in inoculation tests. A collection of powdery mildew on noogoora burr which differed from the cucurbit powdery mildews also infected rockmelon plants in an inoculation test. The collection showed the same characteristics on both the noogoora burr and the rockmelon: the conidia were borne in chains, lacked well-developed fibrosin bodies and produced simple unforked germ tubes. However, it grew sparsely on the rockmelon and soon died. Many of the spores of this fungus produced germ tubes from the end of the conidium whereas in other collections from cucurbits the germ tube usually grew from the side of the conidium.

Details of some representative collections are given below. Full details are given by Ballantyne (1971).

Conidial collections

Citrullus lanatus var. *caffer*, watermelon cv. Blacklee, Rydalmere glasshouse, March, 1963, DAR 7954, B. Ballantyne;

Cucumis melo subspecies *conomon*, oriental pickling melon, C* 46, (U.S.P.I. 157070, L† 90128), Rydalmere, February, 1963, DAR 7914, B. Ballantyne;

C. melo subspecies *melo*, rockmelon (muskmelon) cv. PMR 45, Yoogali, February, 1963, DAR 7984, B. Ballantyne.

C. sativus, cucumber cv. Polaris, Duranbah, October 1963, DAR 12226, F. Autry Hall;

Cucurbita moschata, pumpkin cv. Butternut, C153, Eastwood, February 1964, DAR 12801, B. Ballantyne.

Perithecial collections

Erysiphe cichoracearum. On *Cucumis sativus*, 1951, Dominion Laboratory of Plant Pathology, KP 1798c, KP 1798d, Nova Scotia, Canada, D. Creelman.

Sphaerotheca fuliginea. On *Cucurbita pepo*, 1925, Herbarium mycologicum Romanicum Exsicatti Fasc. 1, No. 19, Herastrau, Romania People's Republic, Tr. Savalescu (ex CUP).

THE HOSTS

Disease reactions as reported in the U.S.A. and observed in New South Wales are given in Table 5.

Rockmelon. In 1963 at Rydalmere, the cultivars Delta Gold, Edisto, PMR Nos. 6, 45 and 88, Rio Gold, Seminole and U.S.P.I. Nos. 124111, 124112 and subline L90209 of 183310 showed no signs of mildew. Other cultivars and U.S.P.I. Nos. were severely affected.

In 1964 at Rydalmere, PMR Nos. 6 and 88, Seminole, LJ 430, breeding lines 151, 157 and 180 of M. B. Hughes, the P. lines (2-9, 10) of G. W. Bohn and U.S.P.I. 234607 were fully resistant. Delta Gold, Edisto, PMR 45, Rio Gold and Wescan were resistant. United States P.I. Nos. 164756, 165525 and 183307 gave mixed reactions with some resistant, some moderately resistant and others susceptible. Florida No. 1 was moderately resistant, Florisun, Floridew and U.S.P.I. 134200 were susceptible and other cultivars were fully susceptible.

In 1964 at Griffith, PMR Nos. 6 and 88, Seminole, 151, 157, 180, LJ 430 and the P lines were fully resistant and PMR 45 and Edisto were fully susceptible. In 1965 at Griffith the same results were obtained except that the P lines were not included. In 1966 at Rydalmere, Campo and Jacumba were fully resistant.

* indicates the accession number of the authors collection.

† indicates the numbers given by the U.S. Horticultural Field Station, La Jolla, which provided seed of such lines.

TABLE 5
Reaction to powdery mildew of lines of *Cucumis melo* in the U.S.A. and in New South Wales

Line	United States of America		New South Wales	
	California and Texas	Eastern States	Rydalmere	Riverina
	Reaction Reference	Reaction Reference	Reaction	Reaction
Group A—cultivars and lines with resistance from one or more of the genes Pm ¹ , Pm ² and Pm ³ . Full details of parentage are in Ballantyne, 1971.				
PMR 45	*S Jagger <i>et al.</i> , 1938	*R Markarian and Harwood, 1967	†R 1963, 1964	†S 1959†
PMR 6	*R Pryor <i>et al.</i> , 1946	*R "	†R 1963, 1964	*R 1959 Anon., 1959 *S 1960 Anon., 1960 †R 1963, 1964, 1965
Wescan	*MR Anon., 1963		†R—1964	
U.S.P.I. 12411	*R Pryor <i>et al.</i> , 1946		†R 1963	*R 1961 Sumeghy, personal communication
LJ 430	*R Bohn, personal communication		†R 1964	†R 1964, 1965
Campo	*R Bohn <i>et al.</i> , 1965	*R Markarian and Harwood, 1967	†R 1966	
Jacumba	*R "		†R 1966	
PMR 88	*R Bohn, 1958		†R 1963, 1964	†R 1964, 1965
P2-P8 P10 8 lines	*R Bohn, 1961		†R 1964	†R 1964

TABLE 5—Continued
 Reaction to powdery mildew of lines of *Cucumis melo* in the U.S.A. and in New South Wales

Line	United States of America		New South Wales	
	California and Texas	Eastern States	Rydalmere	Riverina
	Reaction Reference	Reaction Reference	Reaction	Reaction
Group B—cultivars and lines with resistance most likely governed by one or more of the genes Pm ⁴ and Pm ⁵ .				
U.S.P.I. 124112 4 lines	*R Pryor <i>et al.</i> , 1946		†R 1963	*R 1961 Sumeghy, personal communication
Seminole	*MR Bohn, personal communication	*R Whitner, 1960 Markarian and Harwood, 1967	†R 1963, 1964	†R 1963, 1964, 1965
Delta Gold	*R	Brown <i>et al.</i> , 1960	†R 1963 †R-1964	†R-1962†, 1963†
Florida No. 1	*MR	Jamison <i>et al.</i> , 1963	†MR 1964	
151				
157	*R	Hughes, personal communication	†R 1964	†R 1964, 1965
180				
Group C—cultivars and lines with resistance from genes which have not been identified or designated.				
Rio Gold	*S Correa, personal communication	*R Epps, 1956 Kelbert, 1956 Whitner, 1956	†R 1963 †R-1964	
Edisto	*S Bohn, personal communication	*R 1957 Hughes, personal communication 1958†	†R 1963 †R-1964	†S 1964
Florism	*MR *very low level resistance	Jamison <i>et al.</i> , 1963 Markarian and Harwood, 1968b	†S-1964	

Continued overleaf

TABLE 5—Continued
Reaction to powdery mildew of lines of Cucumis melo in the U.S.A. and in New South Wales

Line	United States of America		New South Wales	
	California and Texas	Eastern States	Rydalmere	Riverina
	Reaction Reference	Reaction Reference	Reaction	Reaction
Floridew		*MR *very low level resistance	†S- 1964	
U.S.P.I. 134200	*R Pryor <i>et al.</i> , 1946	*S Mortensen, personal communication	†S- 1964	
U.S.P.I. 164756§		*R Mortensen, 1961	†7 R 1964 †1 S	
U.S.P.I. 165525		*R Mortensen, 1961	†7 R 1964 †1 MR	
U.S.P.I. 183307	*R Langford and Killinger, 1961	*R Mortensen, 1961	†1 R 1964 †2 MR †5 S	
U.S.P.I. 183310	*S Whitaker, personal communication		†R 1963	*R 1961
90209				
90211	*S "		†S 1963	*S 1961 Stumeghy, personal communication
U.S.P.I. 234607		*R Mortensen, personal communication	†R 1964	

* denotes results reported by other workers.

† denotes results of the author.

R = Resistant

MR = Moderately resistant

S = Susceptible

‡ observations made on commercial plantings.

§ Lines from open-pollinated fruit.

Exact description of these terms as used in this work is on p. 108.

Cucumber. In 1964 at Rydalmere, Pixie and Polaris were resistant, Ashley, Palomar and Stono were moderately resistant, U.S.P.I. 197087 gave a mixed reaction with two plants moderately resistant and the other two susceptible. This plant introduction was probably not a pure line (Barnes, personal communication). Other cultivars and U.S.P.I. Nos. were susceptible including 179260 and 181910 (probably not pure lines [Bohn, personal communication]) on which Randall and Menzies (1956) recorded perithecia of *E. cichoracearum* in the U.S.A. No perithecia of any mildew fungus were seen on these introductions in this trial or on any other cucurbit host in New South Wales.

Cucurbita species. In 1964 at Rydalmere two plants of *C. lundelliana* which produced mature fruit were moderately resistant, one which did not produce mature fruit was resistant and the fourth was fully resistant. Other cultivars of *C. maxima*, *C. moschata* and *C. pepo* were susceptible.

DISCUSSION

Considerable confusion has arisen in the literature because the name of the perfect stage of a powdery mildew fungus has so commonly been given to the imperfect stage without adequate identification. There is no doubt that both *E. cichoracearum* and *S. fuliginea* can occur on cucurbits in several countries, e.g. India and the U.S.S.R., because perithecia of these two fungi have been recorded on several occasions.

Before 1958 *E. cichoracearum* had generally been assumed to be the most common and widespread powdery mildew species reported on Cucurbitaceae. However, this investigation and recent reports from many countries indicate that a mildew having major features of the imperfect stage of *S. fuliginea* is the predominant mildew in some countries, and probably the only species in others. Only two instances of an imperfect stage resembling *E. cichoracearum* have been reported on cucurbits. One was in Hawaii on *Momordica charantia* and *Sechium edule*. The other was in Hungary where two powdery mildews commonly occur on cucurbits; one identified as *S. fuliginea* from perithecia, and the other identified as *E. cichoracearum* on conidial characteristics (Nagy, 1970).

All naturally infected collections of cucurbit powdery mildew from many areas and a wide range of climates in New South Wales resembled the imperfect stage of *S. fuliginea*. The poor vigour of the mildew resembling *E. cichoracearum* from noogoora burr when artificially inoculated on to rockmelon suggests that this fungus is not important on cucurbits in the field in New South Wales.

Observations by many investigators support the contention that the type of conidiophore, the presence or absence of well-developed fibrosin bodies and the mode of germination are useful criteria for distinguishing between the powdery mildew species recorded on cucurbits. The very consistent data obtained in the present study also support this. The reliability of these characters could be further checked by culturing these species from ascospores under controlled conditions and examining the colonies. In addition, characters which would permit mixtures of species to be detected would be valuable if these could be found. The conidial dimensions of *E. cichoracearum*, *E. polygoni* and *S. fuliginea* have generally been considered to be too similar to be of value in distinguishing these species. Nagy (1970) compared length: width ratios of two cucurbit powdery mildew fungi in Hungary; one was identified as *S. fuliginea* on the basis of perithecial characteristics and the other as *E. cichoracearum* from the morphology of the conidia. He found that the length: width ratio was significantly different for the two species. However, he only quoted mean measurements for length, width and the ratio between. The range of measurements of 50 conidia was not given.

It is considered that the mildew present on naturally infected cucurbits in New South Wales is the imperfect stage of *S. fuliginea*.

Many cultivars, breeding lines and plant introductions of several species of cucurbits with reported resistance to *E. cichoracearum* were shown to have resistance to a fungus resembling *S. fuliginea* in this investigation.

Tables 4 and 5 show that there is generally a close similarity in powdery mildew reaction in different countries of various species and cultivars with different genes and sources of resistance. An exception is in the reports of Kooistra (1968), who found only slight resistance in many of the cucumber lines reported to have a higher degree of resistance in other countries. However, his testing was carried out under glasshouse conditions which are very favourable for powdery mildew development and in which reactions cannot be regarded as typical of field behaviour. Leppik (1966*a*) reported that some lines with good resistance in the field showed less resistance under glasshouse conditions.

Some cultivars have a long history of resistance whereas others have resistance when first grown and are later affected by another race of the fungus. For example, the rockmelon cultivar PMR 45, whose resistance is due to the single dominant gene Pm¹, was resistant when first grown in California, New South Wales and Israel but later was affected by a new race in these three areas. There have been no reports of the disease affecting cultivars such as Campo and Jacumba, whose resistance may be derived from several genes including one from U.S.P.I. 124111. Where breeding programmes are being initiated or new sources of resistance are being introduced into existing programmes, preference should be given to lines having a history of resistance in several areas, including some where races capable of severely affecting a range of cultivars are present. The race 2 which occurs in California and Texas appears to be similar to the race which occurs in south western New South Wales, except that the rockmelon cultivar Seminole, which has shown no sign of mildew here, is only moderately resistant in California. It is likely that the races designated 1 and 2 are both complexes of races.

The severe outbreak of powdery mildew on the cultivar PMR 6 in the 1960 season and its resistance in the 1959, 1963, 1964 and 1965 seasons could be due to the disappearance of the PMR 6—attacking form at the end of the 1960 season. The conidia are short-lived and winter conditions in inland and southern coastal New South Wales are too cold for survival of cucurbits. Perithecia have not been found despite thorough search and overwintering on some other host is therefore considered to be the likely means of survival. Alcorn (1967, 1969) found seven non-cucurbit genera were alternative hosts of the cucurbit powdery mildew fungus in Queensland, but these are sub-tropical or tropical species and do not survive winter conditions in southern New South Wales.

Perithecia of powdery mildew fungi occur commonly in some countries and rarely or not at all in others. Perithecia of numerous powdery mildew species occur frequently in the Northern Hemisphere (Salmon, 1900; Blumer, 1933; Viennot-Bourgin, 1956; Junell, 1967; Saville, 1968 and Solheim, Mycolflora Saximont. Exsicc. various Nos. in Herb. DAR), but perithecia of very few species have been recorded in Australia.

Heterothallism is a possible explanation of perithecia being common in some areas and rare or lacking in others. They may be more common in the centre of origin of the species and rare or lacking in other areas where only one mating type of fungus was introduced.

Perithecial formation is more frequent on some host species and cultivars than others (Yarwood, 1957; Khan and Khan, 1970; Price, 1970). Most records of *S. fuliginea* and *E. cichoracearum* have occurred on *Cucumis sativus* and *Cucurbita pepo* (Tables 1 and 2). Alcorn (1969) distinguished at least four patho-

genically distinct races of the cucurbit powdery mildew resembling *S. fuliginea* in Queensland, all of which infected *Cucumis sativus*, *Cucurbita maxima* and *C. pepo*, but not all infected the two cultivars of *Cucumis melo* and the single cultivar of *Citrullus lanatus* var. *caffer* onto which they were inoculated. Perithecia may occur on particular hosts such as *Cucumis sativus* and *Cucurbita pepo* more often because these are susceptible to a wider range of isolates. The probability of opposite mating types occurring together is therefore greater. More widespread culture of these two species could also be the reason.

Homma (1937) reported that heterothallic species seemed to be more common than homothallic ones in Japan. She showed that an isolate which she identified as *S. fuliginea* on *Taraxacum ceratophorum* DC. was homothallic. However this isolate has smaller than typical conidial and perithecial stages and may be a different species.

Smith (1970) reported heterothallism in four mildew species in England and suggested that any lateness or irregularity in perithecial formation in the field is due to absence of the necessary mating types rather than to an unfavourable environment or the nutritive condition of the host.

One might expect to find resistance in areas where both the pathogen and host have been evolving side by side. Most of the powdery mildew resistant collections of *Cucumis* have been made in the primary, secondary and tertiary gene centres of this genus in Africa, India and nearby Asian areas, where the imperfect stage of the mildew resembles *S. fuliginea* and perithecia of this fungus have been recorded on several occasions. Perithecia of *E. cichoracearum*, which is heterothallic (Morrison, 1961), have also been recorded on cucurbits in some of these countries.

Many powdery mildew-resistant lines of *Cucumis* have been recorded but little resistance has been reported in *Cucurbita*. This could be explained by the presence or absence of powdery mildew in the gene centres in the early stages of evolution of these genera. It is likely that *S. fuliginea* has been present in Africa, India and nearby Asian areas for very long periods of time, as suggested by the occurrence of perithecia. This would have favoured selection of mildew resistance in *Cucumis*. No perithecia of *S. fuliginea* have been recorded on cucurbits in the Americas, although they have been found on other hosts. A mildew resembling the imperfect stage of *S. fuliginea* is common and widespread on cucurbits in North America.

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APPENDIX

POWDERY MILDEW RESISTANT COLLECTIONS AND CULTIVARS

Rockmelon (*Cucumis melo* L.)

Many plant introductions have been collected from Asia, Europe and Africa. Several workers (Pryor *et al.*, 1946 ; Mortensen, 1961, 1962 and personal communication ; Leppik, 1966a ; Corley, 1966 and Oda, 1969) have reported on the reaction of some of these to powdery mildew. Of 202 introductions from Asia, Europe and Africa for which disease resistance was given in Corley's compilation, 56 were resistant to powdery mildew in the U.S.A. Most of these were from India (49) with others from Turkey (2), Africa (1), Iran (1), Peru (1), Saudi

Arabia (1) and the origin of one was not listed. Leppik (1966*a*) reported an additional five resistant introductions from India. Oda (1969) reported four introductions from India and one from Burma had a very high level of resistance to powdery mildew, six from India and one from Nepal had intermediate resistance and three others from India had a low level of resistance.

Resistant Cultivars

Cultivars bred in California and Texas for resistance to race 2 are PMR Nos. 5, 6 and 7 (Pryor *et al.*, 1946), PMR 88 (Bohn, 1958), Wescan (Anon., 1963), Perlita (Anon., 1964), Campo, Jacumba (Bohn *et al.*, 1965), Dulce (Anon., 1969*a*) and Tam-dew (Anon., 1971). Those bred elsewhere in the U.S.A. for powdery mildew-resistance include Georgia 47 (Minges, 1972), Delta Gold (Brown *et al.*, 1960), Seminole (Whitner, 1960), Floridew, Florida No. 1, Florisun (Jamison *et al.*, 1962; 1963), Golden Perfection (Brasher, 1965), Gulfstream (Minges, 1972), Southland (Norton, 1970) and Gulfcoast (Norton, 1971).

Cultivars bred or selected for resistance in other countries are: in Israel, Yokniam 54 and 56 (Ilan, 1963) and Ananas PMR, Pearl of En Dor, Yellow Honeydew E1313 and Green Honeydew E3412 bred with PMR 45, Seminole and Davis X as sources of resistance (Rudich *et al.*, 1969); in Japan, Iyo 1 bred from PMR 5 and Earl's Favourite (Tamai *et al.*, 1962); and in New South Wales, Yanco Treat and Yanco Delight bred from subline 36739 of U.S.P.I. 124111 (Anon., 1969*b*).

Cucumber (*Cucumis sativus* L.)

Powdery mildew resistant collections have been made from Burma, U.S.P.I. Nos. 200815 and 200818 (Wilson *et al.*, 1956); from Japan, U.S.P.I. 279465 and from Ethiopia, U.S.P.I. 233646 (Leppik, 1966*a*), from India, U.S.P.I. 197087 (Barnes, 1961) and from China, several varieties including Vladivostoksky 155, Di-huan-guas and Ty-hy-cy (Mescherov, 1961) and Puerto Rico Nos. 37 and 40 (Roque and Adsuar, 1939; Smith, 1949). Leppik (1966*b*) reported that several wild cucumbers from India were immune and several wild species from Africa were resistant to powdery mildew but they could not be crossed easily with cultivated cucumber.

Resistant Cultivars

Resistance to powdery mildew has been reported in the following cucumbers bred in the U.S.A.: Ashley, Stono and Palomar, three cultivars whose resistance appears to be derived from Puerto Rico 40 (Barnes and Epps, 1956); Polaris, Pixie, Pointsett and Cherokee, four cultivars whose resistance appears to be derived from U.S.P.I. 197087 (Barnes, 1961; Minges, 1972) and Tablegreen, whose source of resistance is unknown (Minges, 1972). The cultivar Natsufushinari is reported to be resistant to powdery mildew in Japan (Hujieda and Akija, 1962) and Fävor is listed as resistant to the disease in Sweden (Banga, 1956).

Cucurbita species

Cucurbita lundelliana L. H. Bailey, the peten gourd, which is cross compatible with the cultivated species of *Cucurbita* (*C. maxima* Duch., *C. moschata* Duch. ex Poir. *C. mixta* Pang. and *C. pepo* L.) has resistance to powdery mildew in the U.S.A. (Whitaker, 1956). Rhodes (1959) developed a gene pool among these species and recovered hybrid plants tolerant to powdery mildew. Whitaker (1965) developed relatively stable lines from crosses involving *C. moschata* and *C. pepo* with *C. lundelliana*. These lines have a higher degree of resistance than the susceptible commercial cultivars. Bemis (personal communication) reported that *C. martinezii* L. H. Bailey has powdery mildew resistance similar to *C. lundelliana*.

THE *GLYCASPIS* SPP. (HOMOPTERA : PSYLLIDAE) ASSOCIATED WITH *EUCALYPTUS CAMALDULENSIS*

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Synopsis

The distributions of three *Glycaspis* spp. populations associated with *Eucalyptus camaldulensis* are illustrated and the distinctive lerp typical of two of the species is figured.

Additional information on the previously recorded distributions and hosts of other *Glycaspis* spp. is given.

Previous studies on the *Glycaspis* spp. associated with *E. camaldulensis* suggested that the three psyllid species which utilise this plant species as host might indicate that the species *E. camaldulensis* consists of more than a single taxon.

The present intensive study of the relevant *Glycaspis* spp., their distributions and host plant associations, indicates that the effects of temperature apparently exert limitations on the distribution of the three species, although there is some broad correspondence between the distributions of these psyllid species and the races of their host eucalypt.

INTRODUCTION

The species *Eucalyptus camaldulensis* Dehnh. has been considered as consisting of a single species (Blake, 1953), of a single species and five varieties (Blakely, 1955), and currently of a single species consisting of two subspecies (Pryor and Johnson, 1971).

These differing interpretations of the species, and the general interest shown by workers in various disciplines (Banks and Hillis, 1969 ; Pryor and Byrne, 1969) suggested that a more comprehensive evaluation of the associated psyllids, *Glycaspis blakei* Moore, *G. brimblecombei* Moore and *G. eremica* Moore, throughout the range of distribution of their host plant, might provide information of value in any taxonomic reassessment of the host.

Banks and Hillis (1969) established an intermingling of their " northern " and " southern " chemotaxa of *E. camaldulensis* in four widely separated localities. An intermingling of two of the three *Glycaspis* spp. associated with this species as host, over an extensive area, had also been determined (Moore, 1970*b*, 1972). It was therefore decided to examine more extensively the distributions of the three *Glycaspis* spp. during this project, and attempt to determine whether nymphs of each of the species surviving to the adult stage, utilised different trees of *E. camaldulensis*, or completed their life cycle on the same tree.

These investigations included that portion of the *E. camaldulensis* distribution encompassed by the Central Australia-Lake Eyre river drainage systems, together with the three psyllid species previously found to be associated with that plant as host.

METHODS

Lerps were collected, and nymphs reared to the adult stage, from a number of localities, particularly in the area where the distributions of *G. blakei* and *G. brimblecombei* were known to overlap. Lerps on portions of leaves from selected trees were held in containers for up to 12 days and were examined daily. Adults bred from these nymphs and lerps were preserved for examination and determination of the species.

Net collections of *Glycaspis* spp. were made at 65 collection sites (Fig. 1 and Table 1), and details of the lerp shapes observed at each site were also recorded.

* Statue Bay, M/S 76, Rockhampton, Queensland, 4700.

TABLE 1

Collection localities for *Glycaspis* spp. Sites 1-64 : collections from *Eucalyptus camaldulensis*.
Site 65 : collections from *Eucalyptus tereticornis*.

Site No.	Location	River or Creek	Lerps Present	Species	Number of Specimens
1	16.7 mls. N. Wentworth	Darling River	O R	<i>brimblecombei</i>	1
				<i>annicola</i>	15
2	31.5 mls. N. Pooncarie	Darling River	O R	<i>brimblecombei</i>	3
				<i>annicola</i>	5
3	42 mls. E. Broken Hill	Stephen Creek	C	<i>eremica</i>	21
4	16 mls. W. Broken Hill	Umberumberka Creek	C	<i>eremica</i>	13
5	Menindee	Darling River	O R	<i>brimblecombei</i>	15
				<i>annicola</i>	14
6	8 mls. S. Wilcannia	Darling River	O R	<i>brimblecombei</i>	14
				<i>annicola</i>	6
7	12 mls. N. Wilcannia	Darling River	? O R	<i>brimblecombei</i>	13
				<i>annicola</i>	2
8	Tilpa	Darling River	C O R	<i>brimblecombei</i>	22
				<i>annicola</i>	1
9	Louth	Darling River	C R	<i>brimblecombei</i>	18
				<i>blakei</i>	5
10	14 mls. S. Bourke	Darling River	C? O R	<i>brimblecombei</i>	18
				<i>blakei</i>	1
11	12 mls. E. Milparinka	Warratta Creek	C	<i>eremica</i>	4
12	9 mls. W. Milparinka	Depot Glen	C	<i>eremica</i>	29
				<i>brimblecombei</i>	5
				<i>blakei</i>	1
13	Wompah Gate	Yalpunga Creek	C O R	<i>eremica</i>	5
				<i>brimblecombei</i>	13
				<i>blakei</i>	1
14	7.3 mls. W. Warri Gate	Stoney Creek	?	<i>eremica</i>	6
				<i>brimblecombei</i>	1
				<i>blakei</i>	1
15	9 mls. NE. Innamincka	Cullyamurra Waterhole Cooper's Creek	O R	<i>brimblecombei</i>	6
				<i>blakei</i>	1
16	9 mls. N. Innamincka	?	C O R	<i>eremica</i>	2
				<i>brimblecombei</i>	2
17	40 mls. N. Innamincka	Patchewara Creek	?	<i>brimblecombei</i>	7
				<i>blakei</i>	2
18	23 mls. S. Cordillo Dns.	?	C R	<i>brimblecombei</i>	8
				<i>blakei</i>	3
19	44 mls. N. Cordillo Dns.	?	O R	<i>brimblecombei</i>	2
				<i>blakei</i>	1
				<i>eremica</i>	1
20	Copley	Leigh Creek	C	<i>eremica</i>	23
21	33 mls. N. Leigh Creek	?	C	"	28
22	22 mls. NW. William Creek	Anna Creek	C	"	11
23	Edwards Creek	Edwards Creek	C O	"	38
24	11 mls. S. Oodnadatta	Allandale Homestead	C O	"	11
25	89 mls. W. Oodnadatta	? Evelyn Creek	C	"	19
26	61 mls. N. Welbourne Hill	? Alberga River	C	"	14
27	75 mls. N. Welbourne Hill	Tarcoonyinna Creek	C	"	5
28	5 mls. N. DeRose Hill	The Marryatt River	C	"	43
29	Mt. Olga (Valley of Winds)	Bubia Creek	C O	"	24
30	Kings Canyon	Kings Creek	C	"	36
31	31 mls. E. Wallarah	Palmer River	C	"	50
32	Henbury	Finke River	C	"	13
33	57 mls. S. Alice Springs	Hugh River	C	"	19
34	Alice Springs	Todd River	C	"	36
35	47 mls. E. Alice Springs	Trephina Creek	C	"	10
36	Ormiston Gorge	?	C	"	13
37	18 mls. N. Alice Springs	16-mile Creek	C	"	33
38	36 mls. N. Alice Springs	Burt Creek	C	"	29
39	44 mls. on Harts Ra. Rd.	Gillen Creek (Sandover)	C	<i>eremica</i>	22

TABLE 1—*continued*

Site No.	Location	River or Creek	Lerps Present	Species	Number of Specimens
40	84 mls. E. Harts Ra. Police Station	Marshall River	C R	<i>eremica</i> <i>blakei</i> <i>brimblecombei</i>	5 4 2
41	81 E. Harts Ra. Police Station	Plenty River	C	<i>eremica</i> <i>brimblecombei</i> <i>blakei</i>	14 2 1
42	14 mls. S. Barrow Creek	?	C	<i>eremica</i>	3
43	25 mls. N. Barrow Creek	Taylor Creek	C	<i>eremica</i>	38
44	Wauchope	?	C	<i>eremica</i>	18
45	Devil's Marbles	—	C R	<i>eremica</i>	15
46	23 mls. N. Wauchope	McLaren Creek	C R	<i>eremica</i> <i>brimblecombei</i>	7 2
47	Daly Waters	?Katherine River	C?O	<i>blakei</i>	9
48	16 mls. S. Renner Springs	Tomlinson Creek	C	<i>blakei</i>	23
49	Attack Creek	Attack Creek	C R	<i>blakei</i>	18
50	6 mls. N. Tennant Creek	Tennant Creek	C O	<i>blakei</i> <i>eremica</i>	6 2
51	8 mls. E. Camooweal	?	C O R	<i>blakei</i>	5
52	62 mls. E. Camooweal	Buckley River	C O	<i>blakei</i>	2
53	3 mls. N. Mt. Isa	Leichhardt River	C	<i>blakei</i> <i>brimblecombei</i>	7 1
54	2 mls. E. Mt. Isa	Breakaway Creek	C O R	<i>blakei</i>	19
55	Urandangi	Georgina River	C O	<i>blakei</i> <i>brimblecombei</i>	34 1
56	66 mls. S. Dajarra	?	C R	<i>blakei</i> <i>brimblecombei</i>	17 2
57	Boulia	Burke River	C R	<i>blakei</i> <i>brimblecombei</i>	6 4
58	23 mls. SE. Springvale	Diamantina River	C R	<i>blakei</i>	1
59	104 mls. W. Windorah	Farrar's Creek	C R	<i>blakei</i>	1
60	7 mls. NE. Windorah	Cooper's Creek	C?O	<i>blakei</i> <i>brimblecombei</i>	18 2
61	Isisford	Barcoo River	C O R	<i>blakei</i>	9
62	10 mls. NW. Longreach	Dingo Crk. (Thompson R.)	C R	<i>brimblecombei</i>	2
63	Alice	Alice River	C O R	<i>blakei</i> <i>brimblecombei</i>	5 1
64	E. of Drummond Range	Medway Creek	C O R	<i>blakei</i> <i>brimblecombei</i>	4 1
From <i>E. tereticornis</i>					
65	Meteor Creek	Meteor Creek	C O R	<i>brimblecombei</i> <i>blakei</i>	13 3

Total specimens examined : 1082

Lerp shape : C = clover leaf ; O = oval ; R = round

All insect material has been placed in The Australian National Insect Collection, C.S.I.R.O., Canberra, A.C.T. Methods of storage and treatment of specimens for examination and identification were essentially as those previously recorded (Moore, 1961, 1964, 1970a).

A sample of buds, seed capsules and mature leaves, when each or all were available, was obtained from a selected tree of *E. camaldulensis* on which *Glycaspis* lerps occurred, at each collection site. Corresponding site numbers on aluminium labels were attached to the samples which have been lodged, together with relevant details of the sites, with the New South Wales National Herbarium, Royal Botanic Gardens, Sydney, N.S.W.

RESULTS

A. *Glycaspis* spp. associated with *E. camaldulensis*.

An extensive area where the three *Glycaspis* spp. *blakei*, *brimblecombei* and *eremica* intermingle, was determined. This approximate area is delimited by the heavier outline in Fig. 1.

From the rearing of nymphs to the adult stage, it was found that two or more of these *Glycaspis* spp. were able to coexist and survive on the same tree. The non-selectivity between trees of *E. camaldulensis* by these three species in areas where they intermingle therefore lessens the likelihood that they indicate

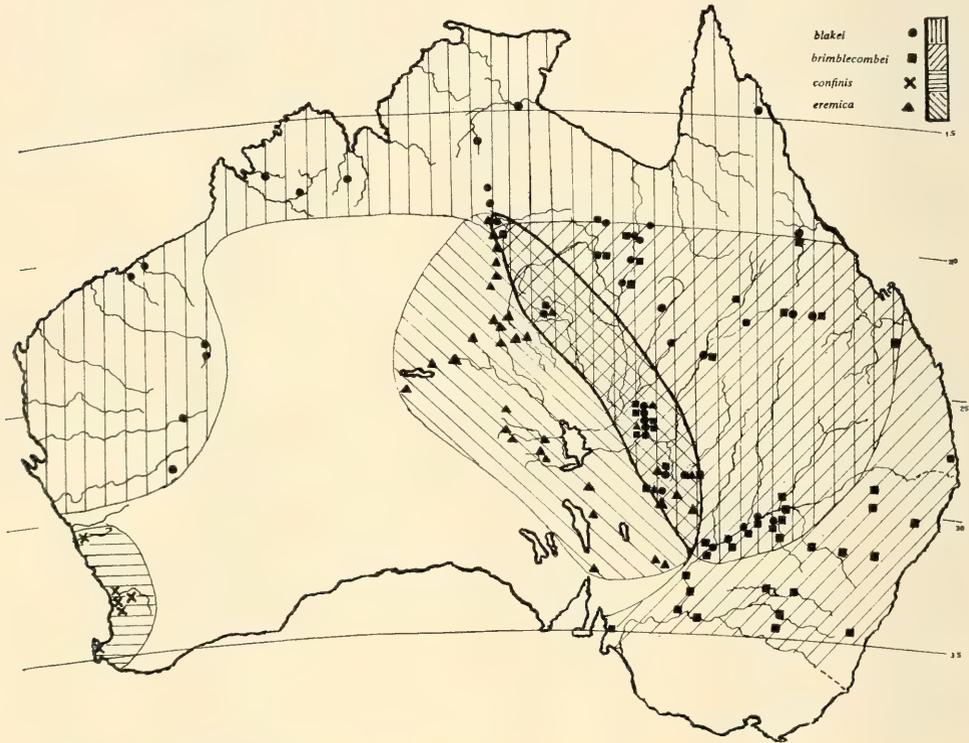


Fig. 1. Distributions of three *Glycaspis* spp. on *Eucalyptus camaldulensis*, and of *G. confinis* on *E. rudis* and *E. cornuta*.

separate taxa of their host plant, at least in that area of intermingling. Nevertheless, their known distributions and overlap may indicate, in a broad sense, the approximate areas of distribution for more than a single taxon of *E. camaldulensis*.

The typical shape of lerps constructed by *G. blakei* and *G. eremica*, atypical of those constructed by other species of *Glycaspis*, are illustrated in Fig. 2, and the general shape suggests the name "cloverleaf" lerps. Each lerp is constructed by a different nymph, and the figure illustrates the superimposed lerps of three nymphal instars. Lerps are usually white, or rarely yellow, and their composition appears similar to that of lerps of other species in the subgenus *Glycaspis*. The close phylogenetic relationship of these two species, as previously indicated (Moore, 1970a), is thus confirmed by the lerp shapes. A few lerps were different in shape, being more or less like a Maltese Cross (i.e. with two crossbars at right

angles) or single-bar-shaped. These aberrant lerp shapes were not investigated, but it is suggested that such atypical forms might result from parasitism of the associated nymph.

The distribution of *G. blakei* was not found to extend southwards beyond its previously determined southern limit at Wilcannia, New South Wales. It occurred in large numbers on *E. tereticornis* Sm. at Site 65 (Meteor Creek, Queensland), adult specimens of this species and of *G. brimblecombei* being reared from the sample tree. Although *E. tereticornis* is plentiful from that site eastward to the coast, an investigation of this area revealed no further cloverleaf lerp. The occurrence of *G. blakei* on *E. tereticornis* is a new host record for this species.

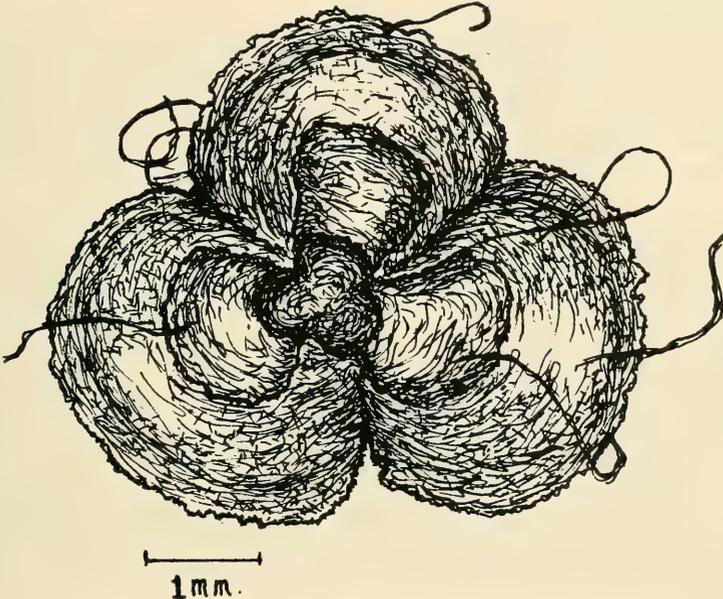


Fig. 2. Cloverleaf lerp typical of *G. blakei* and *G. eremica*.

Known only from west of the Darling River, *G. eremica* intermingles with *G. blakei* and *G. brimblecombei* at a few sites in the drier inland areas of the Northern Territory, Queensland, South Australia and New South Wales, although it occurs alone, throughout the greater portion of its range (Fig. 1).

The species *G. gradata* Moore, previously recorded as possibly occurring on *E. camaldulensis* and *E. largiflorens* F. Muell., was not obtained during this project. Its absence from the intensively sampled former host thus might be interpreted as indicating that its correct host is *E. largiflorens*, and from its distribution records, other closely related "box" species also. It is possible that adverse seasonal factors may have prohibited its occurrence on *E. camaldulensis* during these investigations, but this seems unlikely.

At Sites 1 to 10, round lerp were utilised for rearing *Glycaspis* spp. nymphs to the adult stage for determination of the species. Table 1 indicates that lerp of *G. amnicola* Moore intermingle with those of *G. brimblecombei* on the same tree. *G. amnicola* was previously recorded as constructing oval lerp, but it is now evident that many of the lerp of this species are round, as shown by emergences from the lerp used in the rearing of nymphs, and they are apparently indistinguishable from the round lerp of *G. brimblecombei*. It is maintained that some lerp of *G. amnicola* are oval, thus indicating a possible transitional evolution-

ary stage from the formation of round to oval lerps by nymphs of *G. amnicola*. Northwards from Site 8 (Tilpa) *G. amnicola* was replaced by *G. blakei*, and the former species now is known to coexist with *G. brimblecombei* from Euston on the Murray River, along the Darling River to Tilpa.

B. *Glycaspis* spp. associated with other hosts.

Additional collections for *Glycaspis* specimens were made from a number of other hosts. Results, arranged according to the subgeneric classification of *Eucalyptus* and the system of coded species of Pryor and Johnson (1971), are now given.

(i) Subgenus *Blakella*

Species BAA :A *Eucalyptus tessellaris* F. Muell. was sampled in several areas, but no *Glycaspis* specimens were obtained or lerps observed. It is now considered that this species is most unlikely to be a host of *Glycaspis* spp., even though it was recorded as a possible host of *G. brunneincincta* Moore (1970a). This conclusion is consistent with previously recorded results of collections from other eucalypt species in this subgenus (Moore, 1970b).

(ii) Subgenus *Eudesmia*

Species EAADC *E. odontocarpa* F. Muell. was sampled in three widely separated areas. No *Glycaspis* specimens or their lerps were obtained or observed, these results being consistent with those previously recorded (Moore, 1970b).

EAADE *E. gamophylla* F. Muell. was sampled in several areas with the same results. This project presented an opportunity to become well acquainted with this eucalypt in the field, and it is now almost certain that the plant previously collected from, at Joffre Falls, Western Australia (Moore, 1970a), was not *E. gamophylla* but probably SNABG *E. brevifolia* F. Muell. At that time, *E. gamophylla* in the field was not familiar to the writer.

EFAAA *E. similis* Maiden was intensively and extensively sampled in one locality, but no *Glycaspis* specimens were obtained, or their lerps observed.

Intensive sampling of EFABA *E. baileyana* F. Muell. in one locality produced the same result.

Within this subgenus, 11 of the 15 species have now been sampled for *Glycaspis* spp. which were obtained only from EAC:A *E. tetradonta* F. Muell., EFC:A *E. miniata* A. Cunn. ex Schau. and EFC:B *E. phoenicea* F. Muell. (Moore, 1970a, 1970b).

(iii) Subgenus *Gaubaea*

GAA:A *E. curtisii* Blakely and White was intensively sampled in one area, but no *Glycaspis* specimens or their lerps were obtained or observed.

GAA:C *E. tenuipes* (Maiden and Blakely) Blakely and White was intensively sampled in one area, with the same results.

(iv) Subgenus *Monocalyptus*

Glycaspis specimens from MATEL *E. radiata* Sieber ex DC. collected by A. Yen of La Trobe University, at Healesville, Victoria, were identified as *G. endasa* Moore. This species was originally collected and named from *E. "robertsonii"* Blakely at Towamba, South Coast, New South Wales, by the writer; however, the trees in that area are *E. radiata* ssp. *radiata*.

(v) Subgenus *Symphomyrtus*

Species SBA:C *E. raveretiana* F. Muell. Trees on Moore's Creek, and in the Botanic Gardens, Rockhampton, Queensland, were sampled for *Glycaspis* and their lerps, but no specimens were obtained or observed.

SIVEO *E. pachyphylla* F. Muell. was previously sampled (Moore, 1970b), when no *Glycaspis* specimens were obtained or lerps observed. During this project it was sampled in two widely separated localities where it was established that *Glycaspis* specimens of the *occidentalis* group were utilising it as host. The species obtained, which constructs round lerps, requires more study before it can be assigned a correct position within the *occidentalis* group of species.

SNABG *E. brevifolia* F. Muell. was sampled at Skull Creek, near Central Mount Stuart, Northern Territory. Adults collected were identified as *G. onychis* Moore, and this becomes the most southern locality where *G. onychis* has been obtained. The previous most southern locality was Joffre Falls, Western Australia.

SNEEB *E. tereticornis* Sm. At Site 65, intermingling round and cloverleaf lerps were collected from the sample tree, and nymphs reared to adults. The species were determined as *G. brimblecombei* and *G. blakei* respectively.

SNEEP *E. camaldulensis*. Additional to the species previously mentioned in this paper, the following *Glycaspis* spp. were obtained during net collections from this plant species :

G. encosia Moore from Sites 15, 18, 19, 31, 59, 60.

G. sudicola Moore from Sites 6, 23, 49.

G. froggatti Moore from Sites 32, 49, 54.

G. buxalis Moore from Site 25.

G. retrusa Moore from Site 51.

The sweeping of these species from the foliage of *E. camaldulensis* does not necessarily mean that the eucalypt is utilised as host by the *Glycaspis* species obtained ; e.g. it has been found that species accidental to the host may often be collected during periods of windy weather. The positions of trees in relation to each other and the prevailing wind direction are also contributing factors ; hence the large number of queried hosts recorded in Moore (1970a). It seems certain that none of the species *G. buxalis*, *G. retrusa* or *G. froggatti* utilise *E. camaldulensis* as host, when their previously recorded hosts are considered. *E. microtheca* F. Muell., which also occurred at each of these sites, is the probable host of these species.

SNEEX *E. exserta* F. Muell. Previously recorded from 34 miles north of Clermont, Queensland, adults of *G. exsertae* Moore were obtained from this host four miles west of Alice, Queensland, and it was verified that their lerps were round in shape. The original description of this species was based on one male specimen only (Moore, 1970a).

SUADE *E. microneura* Maiden and Blakely. *G. froggatti* was previously recorded from this host and eight other eucalypt species, from Nannine in Western Australia to Clermont, Queensland (Moore, 1970a). It has now been collected from this host at two miles east of Mt. Isa, Queensland, where it was verified that the shape of its lerp was round to oval, as previously recorded.

SUADJ *E. cyanoclada* Blakely. This eucalypt species previously had not been sampled for *Glycaspis* specimens. At 56 miles east of Frewena, Northern Territory, adults of *G. retrusa* were obtained during this project, but no lerps were found, although intensively sought.

SUG:A *E. cambageana* Maiden. *G. encosia* was collected from this, its originally recorded host, at 36 miles north of Biloela, Queensland, where its numerous round lerps occurred mainly on the twigs and blossoms, thus indicating its possible affinities with the *occidentalis* group of species.

SUP:Y *E. pruinosa* Schau. was again sampled for *Glycaspis* spp. but, as previously, no adults or lerps were obtained or observed.

(vi) *Melaleuca argentea* W. V. Fitzg.

Specimens of *G. deveva* Moore were obtained from this host at Moonal Creek, 28 miles south-east of Urandangie, Queensland, this record constituting a new host for *G. deveva*. The range of its previously recorded distribution is thus considerably extended.

CONCLUSION

The area where the three *Glycaspis* spp. on *E. camaldulensis* intermingle shows some correlation with the 31°C. summer isotherm. This isotherm extends from the approximate centre of the Northern Territory to the south-eastern corner of that State, the north-eastern corner of South Australia almost to the north-western corner of New South Wales, to south-west and central Queensland, passing from latitude c. 18° S. to c. 28° S., through the four areas of differing summer isohyets of 0 mm to 125 mm, 125 mm to 250 mm, 250 mm to 500 mm and 500 mm to 1000 mm. A temperature effect on the distribution limits of the three *Glycaspis* spp. is thus indicated as the most probable limiting factor.

Collections of the three *Glycaspis* spp. and the sampling of *E. camaldulensis* during this project were necessarily confined to the planned route. Presence or absence of the host on a discrete river or creek contacted at more than one locality, varied considerably; e.g. although the host species was present at Sites 58 and 59, it was absent from the lower reaches of the same watercourse at Birdsville. Differing soil types appeared to be associated with this variability.

The atypical "cloverleaf" lerps of *G. blakei* and *G. eremica* suggest phylogenetic divergence of these two species from the remainder of the species which construct round, oval or rectangular lerps within the subgenus *Glycaspis*.

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BIOGENIC STRUCTURES IN THE ORDOVICIAN BOWAN PARK GROUP, NEW SOUTH WALES

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[Communicated by B. D. Webby]

(Plates v and vi)

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Synopsis

Chondrites, large horizontal meandering burrows, small pellet-filled burrows and burrow-mottled limestones are the main biogenic structures in the Daylesford and Quondong Limestones of the Ordovician Bowan Park Group. Synsedimentary diagenetic phenomena associated with biogenic structures include obliterated primary fabrics, fragmented thin-shelled skeletons and vertically mixed sequences of sediments. The occurrence of burrows in the limestones has influenced the distribution of later alteration such as dolomitisation, grain growth, stylolitisation and silicification. The various burrows occupied consistent and unique facies during deposition of the Daylesford and Quondong Limestones: *Chondrites* occurred in dark grey lime mudstones, wackestones and packstones in intermediate to offshore environments; large horizontal burrows and small pellet-filled burrows occurred in dark grey wackestones and packstones in intermediate environments. These burrows are comparatively rare in grainstones and grey skeletal wackestones/packstones of nearshore environments.

INTRODUCTION

Biogenic structures are common in many sedimentary rocks and there is a considerable literature dealing with their description, environmental significance and role in diagenesis (Simpson, 1957; Seilacher, 1964, 1967). Studies by Seilacher (1962), Farrow (1966), Goldring (1962) and others have shown their importance in unravelling ancient environments. Biogenic structures in modern sediments have been studied using plastic impregnated cores, plastic casts of burrow systems, epoxy relief peels and X-ray radiographs (Frey and Howard, 1969).

Burrows and other evidence of biogenic activity are conspicuous and important in many horizons on the Bowan Park Group (Semeniuk, 1970, 1973*b*). These biogenic structures are significant because of the associated synsedimentary diagenetic effects (particularly the mixing of facies) and because of their consistent occurrence within recurring facies in the sequence. This paper is an account of biogenic structures in the lower two formations of the group, the Daylesford and Quondong Limestones. It deals with burrow description, the role of burrowing organisms in synsedimentary diagenesis and the influence of burrows on later alteration. The occurrences of biogenic structures are placed in an inferred environmental framework of the Daylesford and Quondong Limestones.

This study is based on some 600 samples collected from five section localities (Semeniuk, 1973*a*). Samples were studied as thin sections, polished slabs and acid-etched hand specimens. Numbers prefixed by U.S.G.D. and S.U.P. refer to material catalogued in the petrology and palaeontology sections respectively of the Department of Geology, University of Sydney. Limestone classification of Dunham (1962) is used in this paper. Muddy limestone is used as a collective term for rocks with abundant lime mud, i.e. packstone, wackestone and lime mudstone.

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Outline of stratigraphy

The Ordovician Bowan Park Group (Semeniuk, 1970 ; 1973a) is located in the Central Fold Belt (Packham, 1969) of New South Wales, and crops out in the main limestone belt between Eurimbula and Cowra (Fig. 1). The group disconformably overlies the Cargo Andesite and is disconformably overlain by the Malachi's Hill Beds (Semeniuk, 1970 ; 1973a).

The Bowan Park Group consists mainly of limestone and contains three formations (Semeniuk, 1970 ; 1973a) :

Ballingoole Limestone (top), 280m thick ; mainly massive, generally unfossiliferous limestone ; conformably overlies *Quondong Limestone*, 34m thick ; fossiliferous, thinly bedded limestone and marl ; disconformably overlies *Daylesford Limestone*, 250m thick ; terrigenous sediment and marl in basal part, thinly bedded to massive limestone in middle part, and mainly massive limestone in upper part ; disconformably overlies Cargo Andesite.

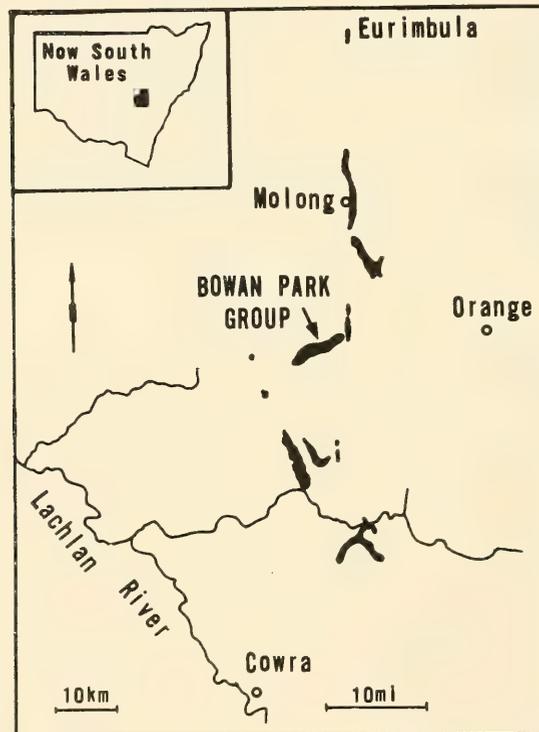


Fig. 1. Location map, distribution of Ordovician limestones between Eurimbula and Cowra and location of the Bowan Park Group.

At the type section the Daylesford Limestone contains six members, which in ascending order are : Ranch Member, Bourimbla Limestone Member, Manooka Limestone Member, Gerybong Limestone Member, Glenrae Limestone Member and Davys Plains Limestone Member. East of the type section, the Oakley Limestone Member is laterally equivalent to the Manooka and Gerybong Limestone Members. Thicknesses and diagnostic lithologies of members are summarised in Table 1.

The Quondong Limestone consists of thinly bedded grainstone, pellet packstone, skeletal wackestone and packstone and lime mudstone. Though not

formally subdivided into members, the formation contains a lower part mainly of thinly bedded grainstone and pellet packstone, and an upper part mainly of marly lime mudstone and pellet packstone.

Lithofacies

The Daylesford and Quondong Limestones contain four main limestone types, and minor intercalations of terrigenous sediment. Limestones are: (1) grainstones, (2) grey skeletal wackestones and packstones, (3) dark grey burrowed wackestones and packstones and (4) dark grey burrowed lime mudstones.

Grainstones are mostly light-coloured and commonly exhibit lamination, cross-lamination and graded bedding. Gravel-sized fossils and pisolites occur in bands and platy grains are arranged parallel to lamination. Most grainstones contain well-sorted, subangular to rounded, medium to coarse sand-sized skeletal

TABLE 1
Daylesford Limestone stratigraphy

Unit	Thickness (metres)	Diagnostic Lithologies
Davys Plains Limestone Member	95	Skeletal lithoclast grainstone, skeletal wackestone and packstone, pellet packstone.
Glenrae Limestone Member	25	Light grey, vuggy and weathered limestone in upper part; intercalated and burrow-mottled grainstone, skeletal wackestone, lime mudstone in lower part.
Oakley Limestone Member	90	Skeletal grainstone, skeletal lithoclast grainstone.
Gerybong Limestone Member	64	Lime mudstone, skeletal wackestone.
Manooka Limestone Member	16	Skeletal grainstone, skeletal lithoclast grainstone, skeletal packstone and wackestone, lime mudstone.
Bourimbla Limestone Member	16	Skeletal wackestone and packstone, lime mudstone.
Ranch Member	34	Unit 3: Skeletal wackestone, lime mudstone, terrigenous mudstone. Unit 2: Skeletal grainstone, packstone and wackestone, skeletal pellet grainstone, lime mudstone. Unit 1: Lithic sandstone, terrigenous mudstone, lime mudstone.

and lithoclast grains. Grey skeletal wackestones and packstones are mostly light grey to medium grey, or, less commonly, dark grey. Burrows are uncommon. Whole gravel-sized fossils are *in situ*, in layers, or randomly oriented. Fragmented, thin-shelled skeletons are angular, poorly-sorted to well-sorted, fine sand- to gravel-sized, and comprise a minor part of the sediment.

Dark grey wackestones and packstones are commonly burrowed, containing gravel-sized and sand-sized whole and fragmented fossils in a dark grey lime mud matrix (skeletal wackestones and packstones); some sediments contain abundant pellets (pellet packstones). Large fossils are oriented in layers, or, more commonly, randomly oriented and disrupted by burrows. Sediments contain abundant poorly-sorted, angular, fine to coarse sand-sized skeletal fragments which are randomly oriented or concentrated in burrows. Skeletal fragments include thin-shelled brachiopods, sponge spicules, dasycladacean algae, ostracods, trilobites, bryozoans, small gastropods and thin-walled coral tubes.

Dark grey lime mudstones are commonly burrowed and consist of clay-sized calcite (micrite of Folk, 1965) and patches of recrystallised micrite (microspar of Folk, 1965); some contain a high proportion of silt- to fine sand-sized skeletal debris. Sand-sized angular fragments of dasyeladacean algae, small gastropods, small thin-shelled brachiopods, ostracods, trilobites and sponge spicules are minor components of the sediment.

Terrigenous sediments include lithic sandstone, and brown and green mudstone. Lithic sandstones are well-laminated, medium to coarse sediments. Brown mudstones are structureless; green mudstones are burrowed, and grade into burrowed, marly lime mudstone.

Stratigraphic relationships of lithofacies

The Bowan Park Group trends approximately east-west for 9 km, and this has permitted analyses of facies changes in a direction probably perpendicular to the palaeo-shoreline (Semeniuk, 1973*b*). Grainstones and grey skeletal wackestones and packstones are more common in eastern sections of the Daylesford Limestone (as evidenced by the Oakley, Bourimbla and Ranch Members) and are laterally equivalent to dark grey lime mudstones, wackestones and packstones that dominate western sections (Semeniuk, 1973*b*). Eastern sections also contain abundant lithoclasts in grainstones; these lithoclasts are absent from the thick muddy sections to the west, except in thin horizons immediately above disconformities.

Lithofacies also tend to occur in sequential arrangement immediately above disconformities. The fully developed, idealised sequences are:

- Type 1. Grainstone grading up into dark grey, burrowed, wackestone (or packstone) which grades into dark grey, burrowed lime mudstone; total average thickness 1.5 m.
- Type 2. Grey skeletal wackestone and packstone (or, in marly sections, brown terrigenous mudstone) grading up into dark grey, burrowed skeletal wackestone and packstone (or green terrigenous mudstone) which grades into dark grey, burrowed lime mudstone; total average thickness 0.5 m.

These sequences are well developed above disconformities in horizons of the Quondong Limestone and in the Ranch, Manooka and Davys Plains Limestone Members of the Daylesford Limestone. Elsewhere, the sequences are only partly developed with either the basal or top lithology absent. Reversals of the sequences may occur beneath disconformities.

DESCRIPTION OF BIOGENIC STRUCTURES

Five types of biogenic structures are represented in the Bowan Park Group: (1) *Chondrites*, (2) large, meandering horizontal burrows, (3) small, pellet-filled burrows, (4) burrow-mottled limestones and (5) borings.

Chondrites

The most common burrow system in the sequence is the ichnogenus *Chondrites*. Burrows are cylindrical, smooth-walled tunnels which branch laterally and regularly (Pl. V, Figs. *a*, *b*, *d*); several orders of branching are developed with tunnels radially arranged (Pl. V, Fig. *a*) and horizontal to gently inclined (Simpson, 1957). Burrow systems are spread on bed surfaces over areas up to 100 sq cm, representing a working area approximately 6 cm radius. Maximum burrow penetration, inferred from vertical slabs, is 6.5 cm; more commonly, burrow penetration is 3.0 to 4.0 cm (Pl. V, Fig. *c*). Tunnel diameter ranges from 1.5 to 3 mm but is constant in any one burrow system; rare tunnels reach

4 mm diameter. Tunnel walls are generally smooth and some are lined with a thin layer of light-coloured carbonate mud (Pl. VI, Fig. *f*), a feature which presumably represents a mucus/mud lining made to maintain burrow walls. Burrows are lined mostly when they occur in sandy host sediments such as packstones and grainstones.

Burrows are filled with sediment, usually lighter in colour than the host sediment. The fill commonly exhibits a concentric lamination in transverse section (Pl. VI, Figs. *a*, *e*) and downward draping of laminae in longitudinal sections. There is no increase in pellet content within burrows as compared with outside, but some burrows contain a high proportion of fragmented skeletal material (Pl. VI, Fig. *e*). Burrows may penetrate lithologically distinct laminae and are filled by sediment similar to the upper layer (Pl. VI, Fig. *e*). Some tunnels are only partly filled with sediment and the remaining void contains sparry calcite cement. Burrows totally filled by sparry calcite are rare. Most of the Bowan Park *Chondrites* appear to have been filled early since filled tunnels are reworked by as many as four later burrows (Pl. VI, Fig. *b*). Although most contemporaneous burrows do not intersect because of some chemical control which prevented the animal from working sediment that already had been exploited, later burrows may intersect earlier ones (Simpson, 1957).

Chondrites occurs in dark grey lime mudstone and dark grey wackestone and packstone that are present in most units of the Daylesford and Quondong Limestones, and in green terrigenous mudstone of Unit 1 of the Ranch Member.

Horizontal meandering burrows

Large meandering burrows that occasionally bifurcate (Pl. V, Fig. *h*), are second in abundance in the sequence. As many as 30 burrows have been found on a square metre of bedding. Burrows are circular in cross section (1 cm diameter) and tend to follow bedding planes, with some extending over distances of 1m. Numerous vertical pipes (1 cm diameter) connect the horizontal tunnels (Pl. V, Fig. *g*).

Tunnels may be partially to completely filled by sandy or silty mud, with sparry calcite filling any remaining pore space (Pl. V, Fig. *f*); some tunnels are lined with carbonate mud forming a smooth wall. Most burrow-fills, however, are partly to completely replaced by a coarse dolomite mosaic (Pl. V, Fig. *g*); the burrow/host sediment contact may also be obliterated. In some, dolomite has advanced beyond the original burrow resulting in vague, cylindrical, interconnected patches of dolomite mosaic.

Large meandering burrows occur in dark grey skeletal wackestone of Bourrimbla, Manooka and Gerybong Limestone Members, in burrowed pellet packstone and skeletal wackestone that occur in the transitional facies between Gerybong Limestone Member and Oakley Limestone Member and also in burrowed pellet packstone at the contact of Quondong and Ballingool Limestones.

Pellet-filled burrows

Small pellet-filled burrows are circular in cross section (1 mm diameter) and consist of meandering and branching tubes up to 3 cm long. Some are lined with carbonate mud. Burrows are filled partly or completely with faecal pellets (Pl. VI, Fig. *a*); sparry calcite fills any void space. These burrows are best developed in dark grey wackestones of the Manooka Limestone Member where they are abundant between the pillars of the receptaculitid *Ischadites* (Semeniuk and Byrnes, 1971). Here the burrows consist of randomly oriented tubes. Small pellet-filled burrows also occur in dark grey skeletal wackestones in Unit 2 of the Ranch Member.

Burrow-mottled limestones

Burrow-mottled limestones are those sediments so thoroughly reworked by burrowers that both the original fabric and the burrow form have been largely destroyed. The limestones vary from homogeneous wackestones and packstones to sediments with patches of grainstone, packstone, wackestone and lime mudstone. Cross sections of small to large burrows are evident in vertical slabs and thin sections but, apart from *Chondrites*, the geometry of most burrows cannot be determined since they have been obliterated by later biogenic activity.

Burrow-mottled limestones occur in some horizons of Manooka Limestone Member, in the transitional facies between Gerybong Limestone Member and Oakley Limestone Member (Fig. 2) and in the Davys Plains Limestone Member.

Borings

Borings are cylindrical holes (generally 2 to 4 mm in diameter) that truncate rock fabrics and sparry calcite mosaics (Pl. VI, Fig. *g*) and indicate tunnelling into cemented sediment. They are commonly filled by contemporary marine sand or later sparry calcite. Borings also occur in brachiopods (Pl. VI, Fig. *h*) and corals; these holes are generally small (0.4 to 0.6 mm diameter) but may reach 5 mm diameter, particularly in corals.

Borings have been found only in grainstones of Manooka and Davys Plains Limestone Members of the Daylesford Limestone, and also in limestones of the Quondong Limestone; where they penetrate rock fabrics they illustrate hard ground conditions were present. Borings, however, are rare in the sequence and will not be discussed further here.

ROLE OF BURROWING ORGANISMS IN SYNSEDIMENTARY DIAGENESIS

Burrowing organisms have affected sediments of the Bowan Park sequence in the following ways: (1) by vertically mixing sequences of facies, (2) by obliterating original fabric and lamination and disorienting large oriented grains within facies and (3) by fragmenting skeletal material.

Vertical mixing of facies

The ability of burrowers to mix a vertical sequence of sediments has important geological implications as the resulting sediment may be a mixture of two or more facies (Logan *et al.*, 1969). Where grain types are facies-restricted and where end-member sediment-types have been found elsewhere within the sequence in a partly mixed or unmixed section, it is possible to ascertain how many lithofacies have been mixed. The problem is easily resolved where one sediment occurs as patches in another.

Burrowing organisms in the Bowan Park sequence have been responsible for mixing of sediments. Detailed studies of some sections have provided comparisons of unmixed, partially mixed, and thoroughly mixed sequences. Sections in Unit 2 of the Ranch Member have illustrated partial mixing. Biogenic reworking has not been intense but infiltration of overlying sediment into burrows has produced a patchy distribution of sediment-types within the beds (Pl. VI, Fig. *c*). In the Manooka Limestone Member, burrowing has been more intense and burrowing organisms have mixed sections which originally consisted of interbedded grainstone, packstone, wackestone and lime mudstone. At the west end of one horizon near the base of the Manooka Limestone Member, for example, grainstone/muddy limestone intercalations were mixed by burrowing organisms to produce a 3 m-thick relatively homogenous burrow-mottled grainstone/packstone bed within a predominantly lime mudstone/skeletal wackestone sequence. Burrowing is less intense 4 km to the east and patches of individual

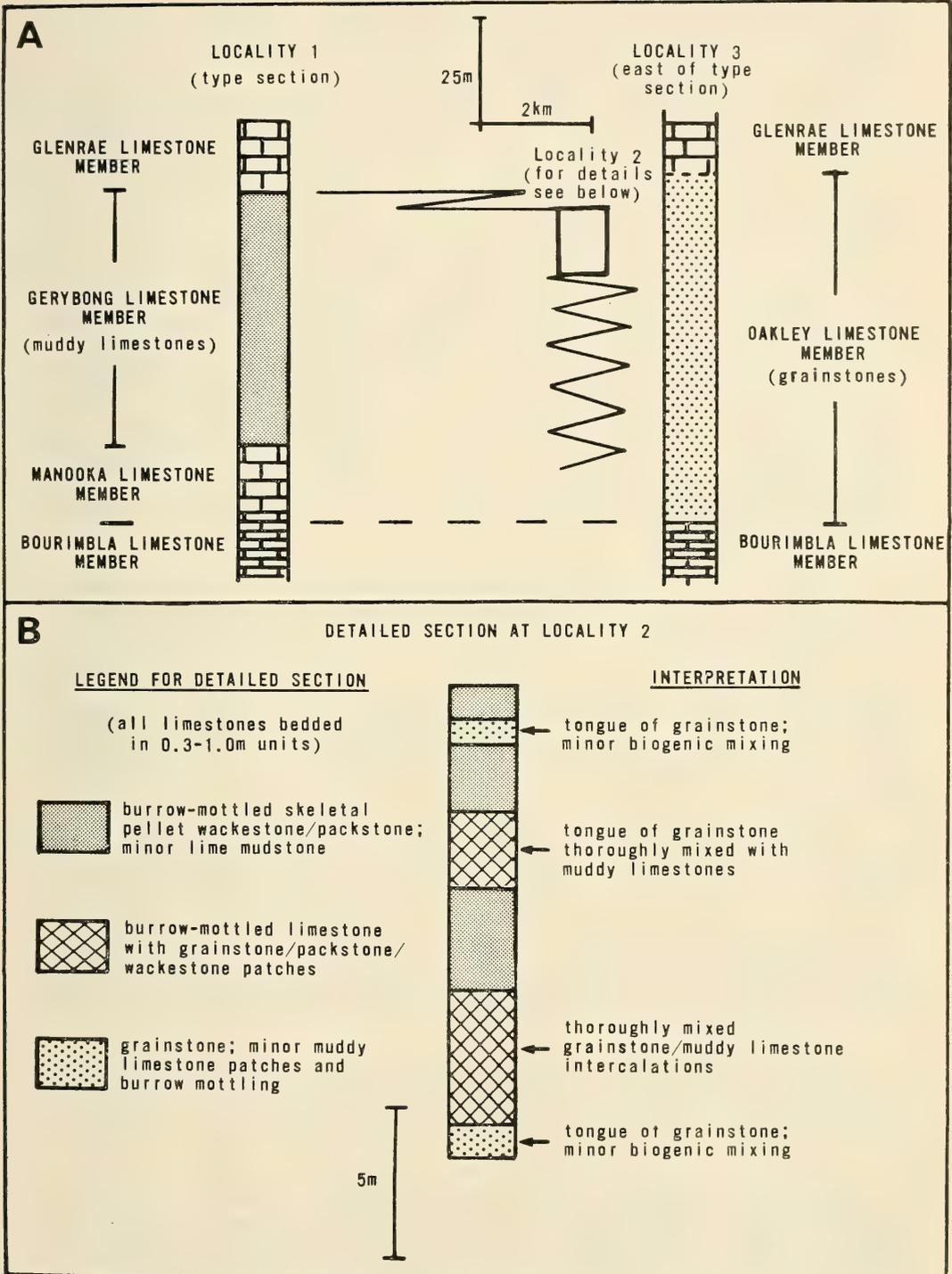


Fig. 2. A. Generalised diagram showing facies relationships between Oakley Limestone and Gerybong Limestone Members. B. Detail at locality 2 of transitional sequence between Oakley Limestone and Gerybong Limestone Members; section illustrates biogenic mixing of interbedded grainstones and muddy limestones.

sediments types are recognisable: the horizon consists of muddy limestone-filled burrows and grainstone-filled burrows within a mottled grainstone to packstone host-sediment. Finally, at the east end of outcrops, only massive grainstone occurs and no burrows are evident.

Similar mixing occurs at localities where burrowed muddy sediments of the Gerybong Limestone Member interfinger with and pass laterally into grainstones of the Oakley Limestone Member (Fig. 2). The transitional section consists mainly of thickly bedded, intercalated grainstone, skeletal pellet wackestone and packstone, pallet packstone, lime mudstone and burrow-mottled mixtures of these sediments. Vertical contacts between sediment types are commonly burrowed.

The results outlined above have been used in the interpretation of environments of the Davys Plains Limestone Member (Semeniuk, 1973*b*). Sediments in the member include grainstone and dark grey muddy limestones. Although unburrowed sediments such as laminated and cross laminated grainstone are recognisable in many horizons, portions of the member consisting of interbedded grainstone/muddy limestone appear to have been mixed by burrowing organisms that kept pace with sedimentation. Burrowing organisms have produced, locally, a burrow-mottled to relatively homogeneous packstone or wackestone where pisolites and rounded sand grains (which are both diagnostic of grainstone lithofacies) occur in a muddy matrix (Pl. VI, Fig. *d*); more commonly, burrowing organisms have produced a mottled limestone in which patches of grainstone and muddy limestone are still discernible.

Obliteration of original fabric

Biogenic activity disrupts primary laminations and other sedimentary structures and ultimately destroys all original fabric (Ginsburg, 1957). In muddy sediments of the Bowan Park sequence, patches of original sediment are observed where burrowing has not been intense. There are two primary fabrics: (1) massive, unlaminated lime mudstone with scattered fossils or (2) skeletal wackestone and packstone with laminae of silt-, sand-, or gravel-sized skeletal debris. Intense burrowing obliterates original fabrics and produces a mottled fabric in which circular to cylindrical outlines of filled tunnels are dominant (Pl. V, Fig. *e*).

Burrows also disrupt oriented larger grains from original bedding positions to form fabrics in which most grains are randomly oriented. For instance, the large brachiopod *Eodinobolus* occurs beak down in growth position or as disarticulated valves oriented convex-up or convex-down in some unburrowed horizons of the Bourimbla Limestone Member. Where burrows occur, articulated and disarticulated valves are found in random orientations. Reorientation of grains is striking where encrusting coralline organisms are present. Coralline organisms would have encrusted only upper portions of shell gravel layers but disruption of the fabric by burrowers has resulted in random orientations of both shells and encrustations.

Burrows generally are uncommon in grainstones, which are bedded with lamination, cross-lamination and graded-bedding. Burrows in these sediments truncate sedimentary structures to varying degrees depending on the intensity of biogenic activity.

Fragmentation of skeletal material

Burrowing organisms can modify grain size (Dapples, 1938; Rhoads, 1967). Feeding, ingestion or the mechanical act of excavating tunnels can comminute skeletal material, particularly if skeletons are fragile. Intense burrowing can produce a sediment composed of angular, highly fragmented shells, explaining how skeletons are highly fragmented in quiet-water environments (Matthews,

1966). In the Bowan Park sequence, weakly burrowed horizons may contain articulated and disarticulated complete valves of thin-shelled brachiopods, together with recognisable sponge spicules, dasycladacean algae, trilobites, ostracods and coral tubes. As burrows become more numerous, thin-shelled skeletons become fragmented and form angular, skeletal sand and silt, which is common in many dark grey burrowed lime mudstones, wackestones and packstones (Pl. VI, Figs. *b*, *e*).

INFLUENCE OF BURROWS ON LATER ALTERATION

Biogenic structures have influenced distribution of some late (diagenetic or low-grade burial metamorphic) alteration phenomena such as dolomitisation, grain growth, silicification and stylolitisation. In addition to undergoing normal diagenesis, limestones of the Bowan Park Group have been subjected to low-temperature burial metamorphism of the prehnite-pumpellyite-metagreywacke facies of Coombs (1960), as evidenced by alteration in the overlying rocks of the Malachi's Hill Beds (Semeniuk, 1970). It has been difficult, however, to differentiate late diagenetic alteration from that produced by burial metamorphism.

Apart from some dolomite associated with faults, stylolites and chert nodules, most dolomite in the sequence is associated with large burrows (Pl. VI, Fig. *g*) and, to a less extent, *Chondrites* burrows. This dolomite commonly connects with thin sheet-like dolomite mosaics that are localised along cracks and stylolites. Dolomite appears to have replaced predominantly burrow-fill sediment, forming a coarse interlocking mosaic with calcite patches in inter-rhomb areas. Dolomitised burrows grade into undolomitised and partly dolomitised burrows; within these latter burrows, burrow-fills commonly are sandier than the enclosing host sediment, suggesting selective dolomitisation of burrow-fills may have been related to the higher porosity of material in burrows relative to the surrounding host sediment.

Many burrow-fill sediments also exhibit grain growth mosaics, especially if there is a contrast in character between burrow-fill material and host sediment. Grain growth is most pronounced where burrows in lime mudstone are filled with grainstone. Sparry calcite cement of the grainstone is recrystallised to the extent that it is poikiloblastic. Wackestone and mudstone filled burrows in a lime mudstone host are recrystallised to a mosaic of microspar (Folk, 1965) while the surrounding host undergoes comparably little or no recrystallisation. This results in burrow-fills which are granular, and lighter-coloured in thin section. Where lime mudstone, wackestone or packstone fills a burrow in grainstone, similar grain growth phenomena occur but mosaics are ragged at the burrow periphery.

Less important alteration phenomena associated with burrows include silicification, where portions of dolomitised burrows are silicified, and stylolitisation, where the stylolites follow the physical discontinuity at the burrow/host rock contact.

OCCURRENCE OF BURROWS WITHIN INFERRED DEPOSITIONAL ENVIRONMENTS

In the Daylesford Limestone, the convergence of disconformities to the east, the dominance of grainstones and grey skeletal wackestones and packstones in eastern sections and the occurrence of lithoclasts in the thick grainstone sequences all suggest a positive area to the east of the depositional basin (Semeniuk, 1973*b*). Grainstones and grey skeletal wackestones and packstones probably bordered the positive area as fringing deposits. Dark grey burrowed muddy limestones occurred in the subsiding area to the west. The convergence of disconformities to the east and similar suites of lithologies within the Quondong Limestone suggest a similar palaeogeographic and environmental setting for this formation.

The lateral facies changes also are reflected (immediately above discontinuities) in the vertical sequences which probably were deposited under transgressive conditions and relate to deepening water. The sequences generally indicate increased effects of burrowing, increased accumulation of mud relative to grains, decreasing energy, and relatively increased reducing conditions.

Grainstones commonly form the base of Type 1 transgressive sequences (p. 132). Grey skeletal wackestones and packstones (or brown terrigenous mudstones) form the base of Type 2 transgressive sequences (p. 132). This stratigraphic position and relationship to the positive area suggests the grainstones and grey skeletal wackestones and packstones are nearshore, shallow water sediments. In marly sequences, brown terrigenous mudstones substituted for grey skeletal wackestones and packstones.

Dark grey burrowed lime mudstones occur at the top of most transgressive successions and predominate in western localities. Abundance of lime mud and lack of shallow water indicators suggest the sediments formed under low energy conditions, probably beneath wave base. These sediments are interpreted as offshore deposits.

Stratigraphically the dark grey burrowed wackestones and packstones generally occur above grainstones (or grey skeletal packstones and wackestones) and below dark grey lime mudstone. The sediments are interpreted as having formed in intermediate depths of water. In marly sequences, green terrigenous mudstones substituted for dark grey wackestones and packstones.

The various burrows occurred in consistent facies throughout deposition of the Daylesford and Quondong Limestones. For instance, *Chondrites* burrows always occur in abundance within dark grey lime mudstones, wackestones and packstones that are interpreted as offshore to intermediate facies, and which are present in all phases of sedimentation of these formations. Bathymetry, rather than sediment type, appears to have controlled their distribution: *Chondrites* burrows are uncommon in all shallow water sediments, e.g. in grey skeletal wackestones and packstones of the Bourimbla Limestone Member and the Quondong Limestone and in grainstones of the Quondong Limestone and Manooka, Oakley and Davys Plains Limestone Members of the Daylesford Limestone. *Chondrites* distribution within reconstructed depositional environments of Ranch, Bourimbla, Manooka, Gerybong and Oakley Limestone Members is illustrated in Fig. 3.

Horizontal meandering burrows occur predominantly in dark grey skeletal wackestones and packstones, sediments interpreted to have formed in intermediate depths of water. The burrows overlap the distribution of *Chondrites*. Their position relative to *Chondrites* is consistent during four depositional phases of the Daylesford Limestone (Fig. 3). Small pellet-filled burrows appear in two units of the Daylesford Limestone; both appearances occur in dark grey skeletal wackestone interpreted as sediments formed at intermediate depths (Fig. 3).

The occurrences of biogenic structures in these unique environmental positions aid environmental interpretation of some vertically or laterally incomplete sections. Where they occur, burrows can be used to infer relative bathymetry. For instance, *Chondrites*-burrowed lime mudstones may be placed as the deepest facies and other sediment types treated as shallow water equivalents. Biogenic structures are used to complement information given by other criteria and there is good correlation between environments suggested by burrows and that suggested by petrographic and palaeontologic data.

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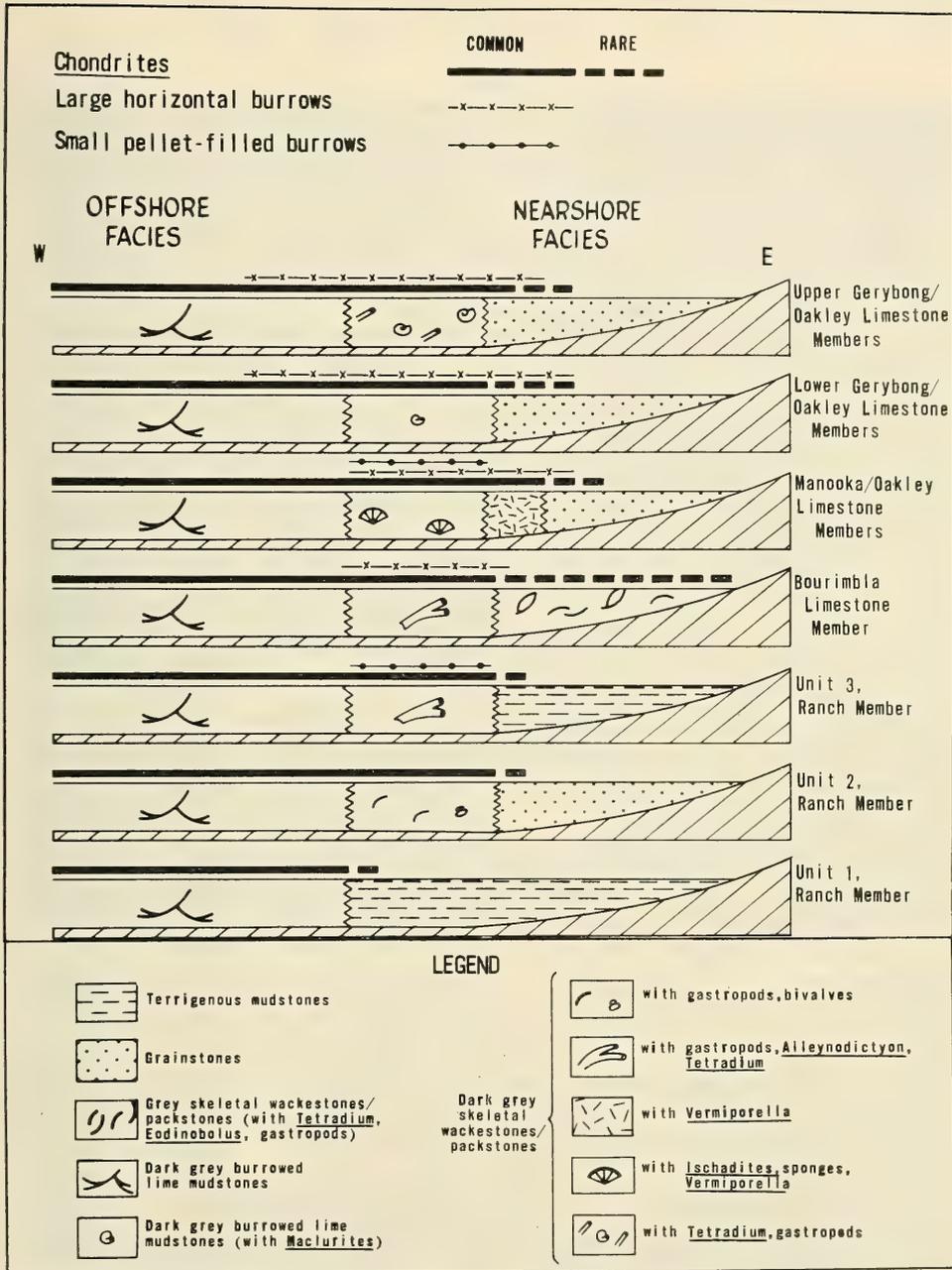


Fig. 3. Distribution of burrow types within reconstructed facies during various phases of sedimentation of lower to middle Daylesford Limestone. (*Alleynodictyon*=cylindrical stromatoporeid; *Eodinobolus*=inarticulate brachiopod; *Ischadites*=receptaculitid; *Vermiporella*=dasycladacean alga).

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EXPLANATION OF PLATES

PLATE V

Fig. a. *Chondrites* burrows showing radial arrangement of tunnels on bedding plane surface of limestone. Upper Bourimbla Limestone Member of Daylesford Limestone, S.U.P. 23859.

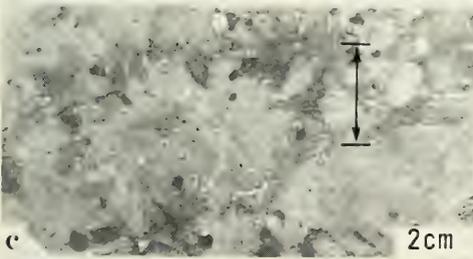
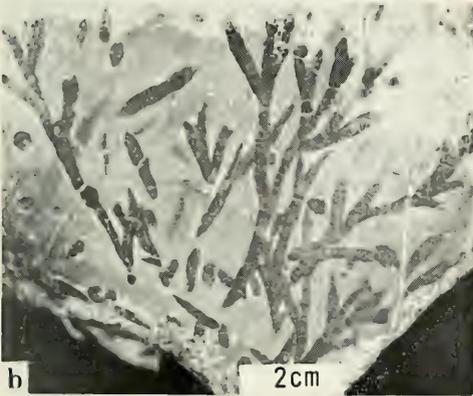
Fig. b. *Chondrites* burrows showing branching pattern of tunnels on bedding plane surface of limestone. Quondong Limestone, S.U.P. 23860.

Fig. c. Vertically oriented slab showing depth of penetration (arrowed) of *Chondrites* burrows. Bourimbla Limestone Member of Daylesford Limestone, U.S.G.D. 42195.

Fig. d. *Chondrites* burrows and large horizontal burrows on bedding plane surface of limestone of upper Gerybong Limestone Member near “Quondong” property. Lens cap diameter approximately 5 cm.

Fig. e. Burrow-mottled fabric produced by intense bioturbation. Ranch Member of Daylesford Limestone, U.S.G.D. 46676, polished slab.

Fig. f. Vertical slab of (undolomitised) large horizontal burrow (left of photo) showing sediment partly filling tunnel and sparry calcite filling remaining void space ; surrounding limestone is burrow-mottled. Glenrae Limestone Member of Daylesford Limestone, U.S.G.D. 46737.



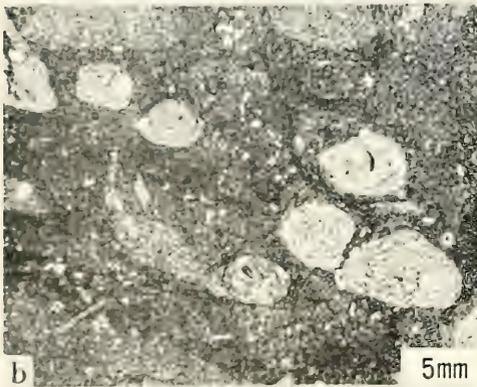
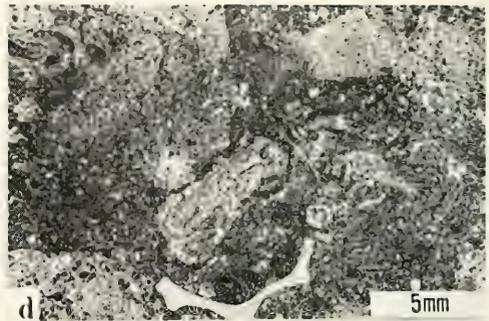


Fig. *g*. Short vertical pipes that connect large horizontal burrows; burrow-fills have been dolomitised. Gerybong Limestone Member of Daylesford Limestone, U.S.G.D. 46732, acid-etched slab.

Fig. *h*. Dolomitised large horizontal meandering and branching burrows on bedding plane surface of limestone of lower Gerybong Limestone Member, 1.5 miles east of "Quondong" homestead.

PLATE VI

Fig. *a*. Small pellet-filled burrows (two are arrowed), and section through *Chondrites* at lower portion of photomicrograph. Ranch Member of Daylesford Limestone, U.S.G.D. 47038, thin section, plane polarised light.

Fig. *b*. *Chondrites* burrows (light grey) transecting earlier burrows (dark grey); note abundance of highly fragmented angular skeletal grains. Ranch Member of Daylesford Limestone, U.S.G.D. 46681, thin section, plane polarised light.

Fig. *c*. *Chondrites* tunnel filled with skeletal wackestone penetrating skeletal pellet grainstone; note concentric lamination exhibited by burrow-fill. Ranch Member of Daylesford Limestone, U.S.G.D. 46671, thin section, plane polarised light.

Fig. *d*. Pisolitic burrow-mottled wackestone/packstone formed by burrowing organisms mixing a pisolitic grainstone and muddy limestone. Davys Plains Limestone Member of Daylesford Limestone, U.S.G.D. 47049, thin section, plane polarised light.

Fig. *e*. Angular skeletal fragments occurring predominantly in *Chondrites* burrows. Gerybong Limestone Member of Daylesford Limestone, U.S.G.D. 41799, thin section, plane polarised light.

Fig. *f*. Carbonate silt (arrowed) lining wall of *Chondrites* burrow. Manooka Limestone Member of Daylesford Limestone, U.S.G.D. 46704, thin section, plane polarised light.

Fig. *g*. Boring in sparry calcite-cemented grainstone; note truncated grain at right margin of bore (arrowed); the hole has been partly filled with sand. Davys Plains Limestone Member of Daylesford Limestone, U.S.G.D. 41814, thin section, plane polarised light.

Fig. *h*. Smooth walled, sparry calcite-filled boring (arrowed) in brachiopod; the hole truncates internal shell structure and is parallel to the shell surface. Quondong Limestone, U.S.G.D. 47043, thin section, plane polarised light.

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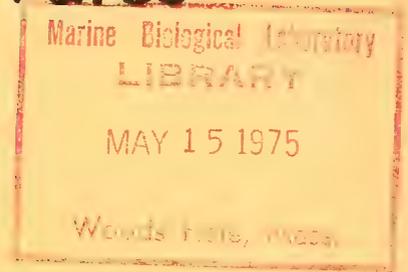
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A NEW SPECIES OF *AMBLYSEIUS* BERLESE
(ACARINA : PHYTOSEIIDAE) FROM APPLE IN AUSTRALIA

H. A. DENMARK* AND E. SCHICHA†

[Accepted for publication 17th April 1974]

Synopsis

A new species of mite (Acarina : Phytoseiidae) is described from apple in New South Wales, Australia : *Amblyseius lentiginosus* Denmark and Schicha n. sp. is closely related to *Amblyseius rhabdus* Denmark.

INTRODUCTION

The species of phytoseiid mite described in this paper was collected in commercial orchards of Granny Smith apple trees at Bathurst, New South Wales. This species was also found in an orchard of young, unbearing apple trees and on single neglected "backyard trees" during the years 1971 to 1973.

Measurements listed are the mean of three specimens in microns.

Genus *AMBLYSEIUS* Berlese

Amblyseius Berlese, 1914, *Redia*, 10 : 143. Type of the genus :

Zercon obtusus Koch, 1839, by indication of Berlese (1914).

Amblyseius (*Amblyseius*) *lentiginosus*, n. sp.

(Figs 1-8)

Diagnosis. *Amblyseius lentiginosus* n. sp. is closely related to *A. rhabdus* Denmark (1965), but the latter has no teeth on the movable digit of the chelicerae and the spermathecal atrium is more rod-like. *A. lentiginosus* has lunate areas and numerous pores on the dorsal shield, three teeth on the movable digit of the chelicerae, and the spermathecal atrium is about twice as wide as in *A. rhabdus*.

FEMALE

Dorsum: The dorsal shield (Fig. 1), length 352-360, width at L_4 199-202, is well sclerotised and smooth, with 11 pairs of pores and 17 pairs of setae, six of which are dorsal, two median (one anterior and one posterior), four prolateral and five postlateral. The setae measure in length :

$D_1=30-36$; $D_2=6$; $D_3=3$; $D_4=7$; $D_5=7$; $D_6=7-8$; $L_1=55-58$; $L_2=7-9$; $L_3=6-7$; $L_4=85-90$; $L_5=7$; L_6 , L_7 and $L_8=7-9$; $L_9=203-210$; $M_1=3-4$; $M_2=123-130$. Setae D_1 , L_1 and L_4 are longer than the distances between their bases and the bases of the setae following next in line. Setae S_1 , 14-16 and S_2 , 9-10 long, are located on the dorsal interscutal membrane.

The peritremes extend forward beyond the bases of setae D_1 .

Venter: The sternal shield (Fig. 2) measures 116-130 in length and 101-109 in width. It bears three setae and two pairs of pores near the first and the third pair of setae. The fourth pair of setae is placed on metasternal shields which each bear a caudomedial pore. The genital shield (Fig. 2), width 80-100, is normal with a pair of setae and a straight posterior margin. The smooth, pentagonal, ventrianal shield (Fig. 2) is 116-130 long and 101-109 wide. It is

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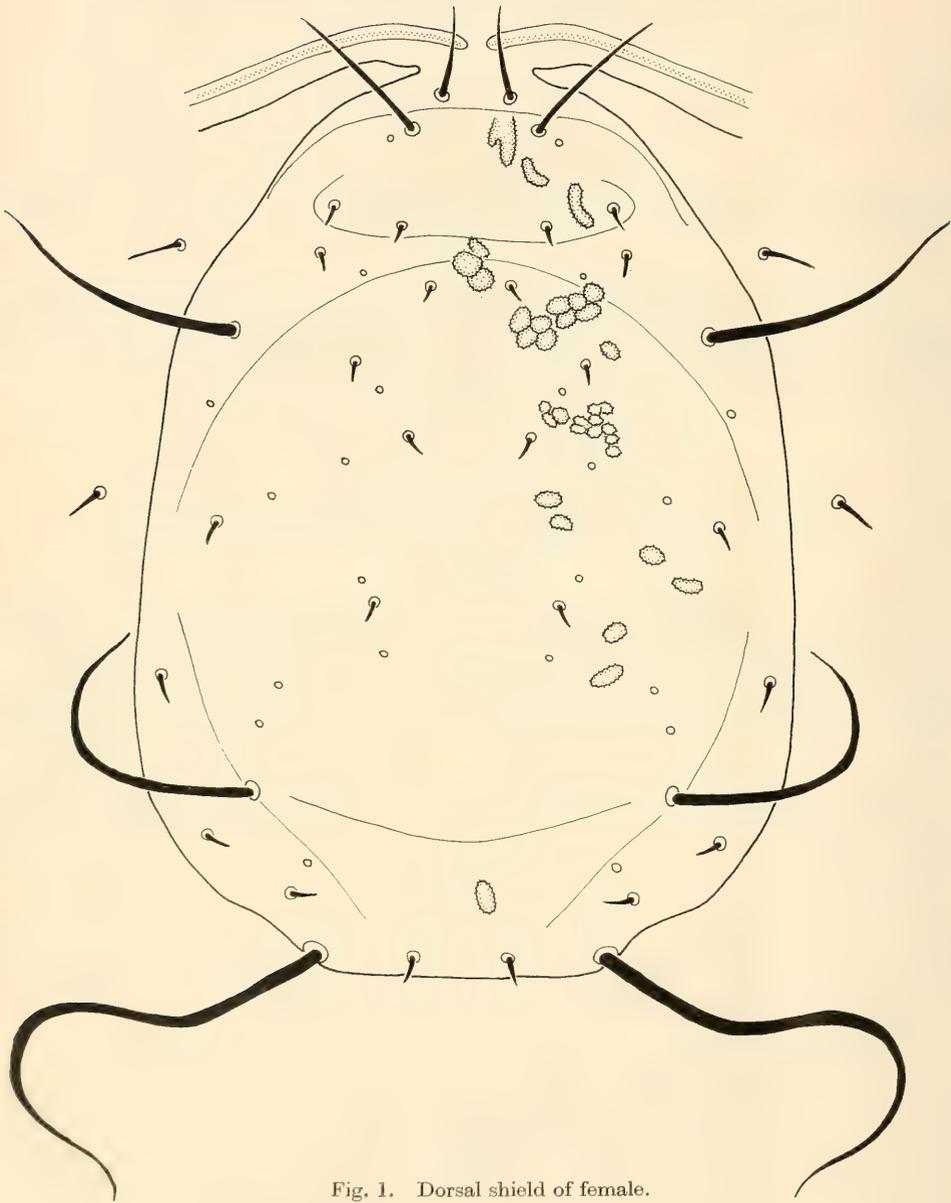


Fig. 1. Dorsal shield of female.

provided with three pairs of preanal setae and a pair of pores caudomedial to the third pair of setae.

Spermatheca : (Fig. 3) The major duct is nearly as broad as the tube-like cervix ; an atrium is not distinct.

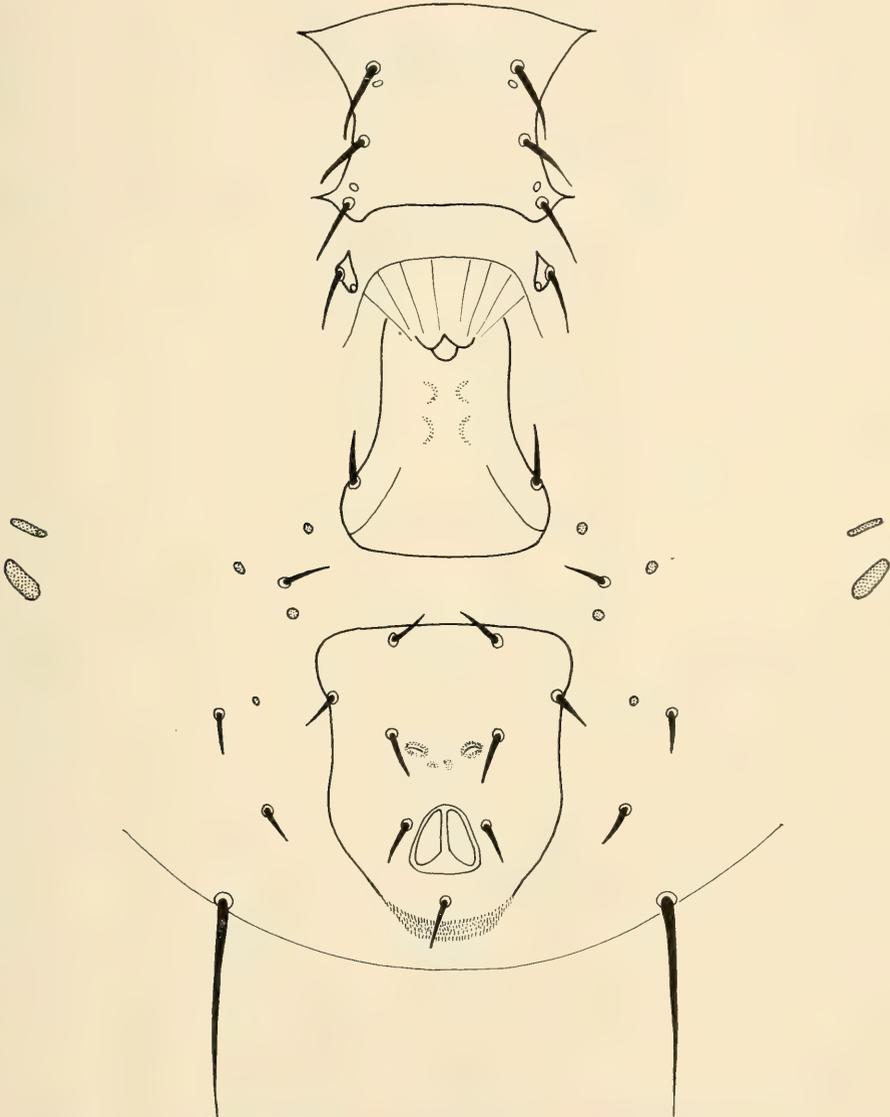


Fig. 2. Venter (sternal shield, genital shield, ventrianal shield) of female.

Chelicera : (Fig. 4) The fixed digit is 40–41 long and bears seven teeth and a pilus dentilis. The movable digit is 50–51 long and is provided with three teeth.

Legs : (Fig. 5) Sge IV, 90–101 ; Sti IV, 91–94 ; St IV, 75–87.

Peritrematal Shield : (Fig. 6).

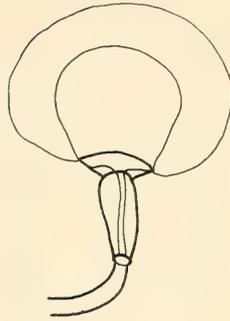


Fig. 3. Spermatheca of female.

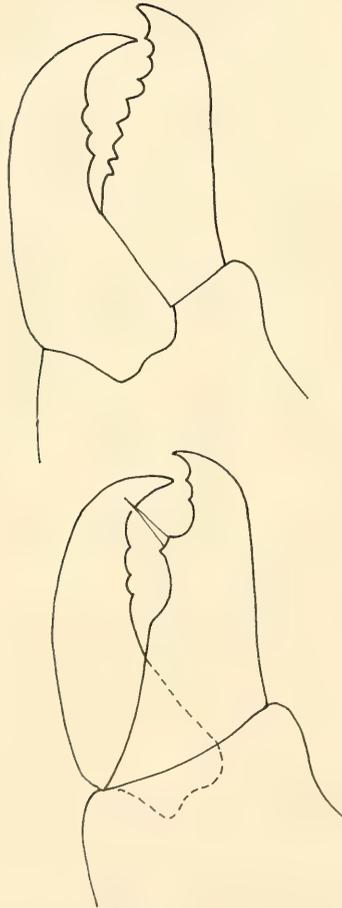


Fig. 4. Chelicera of female.

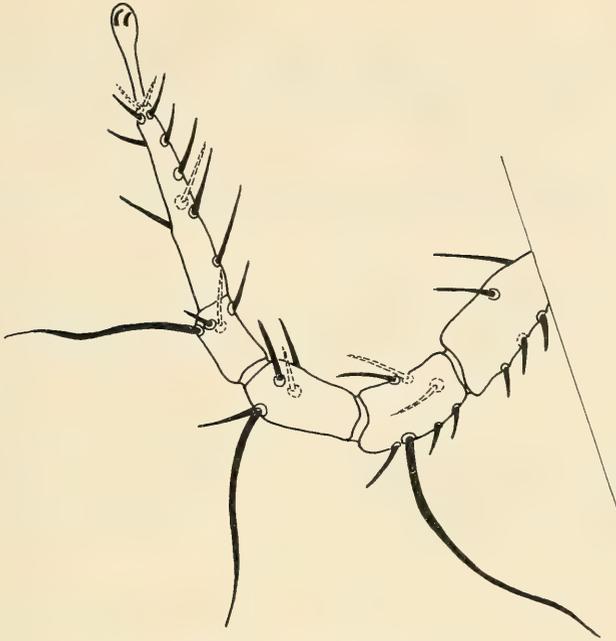


Fig. 5. Leg IV of female.

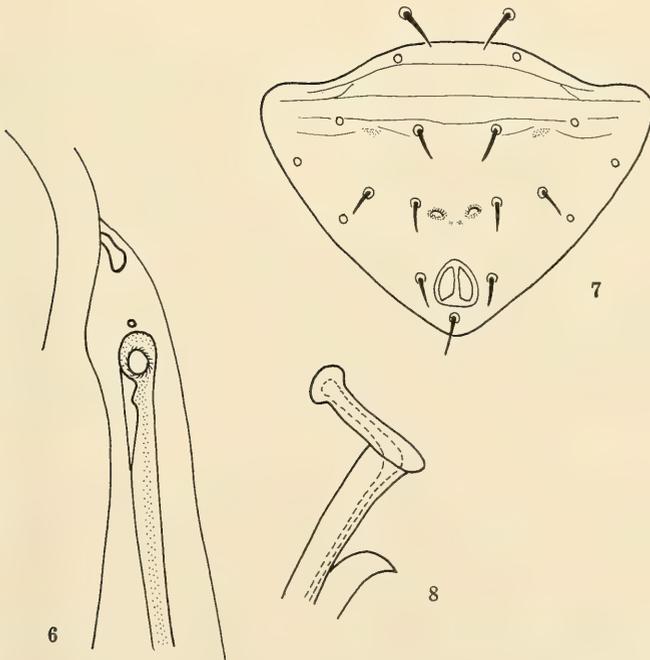


Fig. 6. Peritrematal shield of female.

Fig. 7. Ventrianal shield of male.

Fig. 8. Spermatodactyl of male.

MALE

Dorsum: The dorsal shield measures 283 in length and 199-202 in width at L_4 . The chaetotaxy of the shield resembles that of the female but the setae are shorter. $D_1=22-23$; $D_2=5-7$; $D_3=3-5$; $D_4=3-6$; $D_5=3-6$; $D_6=6-7$; $L_1=38-43$; $L_2=3-7$; $L_3=3-7$; $L_4=72-75$; $L_5=7$; $L_6=7$; $L_7=5-7$; $L_8=6-7$; $L_9=152-154$; $M_1=4-5$; $M_2=87$.

Venter: The ventrianal shield (Fig. 7), length 109 and width 159, bears three pairs of preanal setae and four pairs of pores in addition to a fifth pair which is caudo-medial to the third pair of setae.

Spermatodactyl: (Fig. 8) The lateral process of the foot (length 7-9) is rounded; the toe is a rounded knob.

Holotype. Female from Bathurst, N.S.W., Australia, 28.i.1971, E. Schicha, on apple trees. Deposited in Biological and Chemical Research Institute, Rydalmere, N.S.W., Australia.

Paratypes. Six females and six males taken from the same locality as the holotype. Deposited as follows: two females and two males at Biological and Chemical Research Institute, Rydalmere; two females and two males at Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, Florida, U.S.A.; two females and two males at the South Australian Museum, Adelaide, S.A., Australia.

Reference

DENMARK, H. A., 1965.—Four new Phytoseiidae (Acari: Mesostigmata) from Florida. *Fla Ent.* 48: 89-95.

A NEW SPECIES OF TILEFISH (FAMILY BRANCHIOSTEGIDAE)
FROM EASTERN AUSTRALIA

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[Accepted for publication 20th March 1974]

Synopsis

Until recently the genus *Branchiostegus* was represented in Australia only by *B. wardi*, thought to be restricted to waters off southern Queensland and New South Wales. A specimen of this species has been taken recently from New Caledonia and a new species of *Branchiostegus* trawled off New South Wales. The new form is characterised by a colour pattern of 18–19 black body bars, two broad yellow bands on the caudal fin, yellow spots on the dorsal fin and 67–72 pored lateral line scales. Both Australian species are benthic carnivores. *B. wardi* appears to spawn a number of times per year.

INTRODUCTION

The genus *Branchiostegus* is represented by eleven nominal species found mainly in the tropical Indo-Pacific; exceptions are *B. semifasciatus* from West Africa and *B. sawakinensis* which ranges into the Red Sea from the Indian Ocean. The only species previously known from Australia, *B. wardi*, is not restricted to the tropics but occurs off southern Queensland and New South Wales (Marshall, 1965).

A revision of the family Branchiostegidae has recently been completed (Dooley, 1974). During this study a second Australian species became apparent which is strikingly different from *B. wardi*, particularly in colour pattern.

MATERIALS AND METHODS

Measurements were made with dial calipers to the nearest 0.5 mm and conform to those defined by Hubbs and Lagler (1958). Measurements are expressed as per cent standard length (SL) or per cent head length (HL). Head length was taken from the tip of the snout to the tip of the opercular spine. Cheek depth was measured vertically from the lower rim of the orbit to the lower margin of the preoperculum. Opercular length is the horizontal distance from preoperculum to opercular spine; opercular scale counts were also made along this line. Vertebral counts were made from radiographs.

The holotype has been deposited at the Australian Museum, Sydney (AMS) and the paratypes at the Australian Museum, at the Queensland Museum, Brisbane (QM), at the California Academy of Sciences, San Francisco (CAS), at the United States National Natural History Museum, Washington, D.C. (USNM), at the British Museum of Natural History, London (BMNH) and at the Museum National d'Histoire Naturelle, Paris (MNHN). All specimens were obtained by bottom trawl.

Branchiostegus serratus n. sp.

Holotype. AMS I. 16207–004, 285 mm SL, Newcastle, New South Wales, Australia, 8 May 1971, Sydney Fish Markets, J. Paxton.

Paratypes. New South Wales: AMS I. 16207–002, USNM 209532, USNM 209533, (3) 245–290 mm SL, data as holotype; AMS I. 15916–003, –004, –005,

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-006, (4) 263-275 mm SL, Newcastle, 2 Feb. 1971, N.S.W. State Fisheries; AMS IB. 5074, 240 mm SL, off Lake Illawarra, Jan. 1961, J. Woore; AMS I. 15885-006, 228 mm SL, Newcastle (33° 13'-32' S; 151° 50'-52' E), 27 Oct. 1970, 110-150 m depth, T. Gorman and T. Johnson; AMS IB. 2908, 405 mm SL, off Coff's Harbour, 21 Jan. 1953, J. Woore; AMS I. 17312-001, -002, -003, -004, (4) 237-302 mm SL, BMNH 1973.7.17.3, 232 mm SL, MNHN 1973-36, 235 mm SL, CAS 28355, 229 mm SL, Newcastle, Sept. 1971, Sydney Fish Markets, J. Paxton. Queensland: QM I-8707, 268 mm SL, N.E. Cape Moreton, 162 m depth; QM I-8968, 213 mm SL, off Cape Moreton.

Diagnosis. The new species is distinguished from all congeners by the following combination of characters: the presence of a series of 18 or 19 dark vertical bars on the dorsal portion of the body, 67-72 pored lateral line scales, usually seven dorsal spines and the absence of dark pigmented areas on the operculum, dorsal head ridge and pectoral axillae.

DESCRIPTION

The following counts are of the holotype, with those showing variation in the 19 paratypes in parentheses: dorsal fin rays VII, 15 (VI (2), VII (17)); anal II, 12 (12 or 13); pectoral 17 (17 or 18); pelvic I, 5; principal caudal rays 17; cheek scales from preopercular angle to orbital rim 10 (10-13); opercular scale

TABLE 1
Frequency distribution of pored lateral line scales in Branchiostegus wardi and B. serratus

	48	49	50	51	52-66	67	68	69	70	71	72	\bar{X}
<i>B. wardi</i>	2	11	4	1				49.2
<i>B. serratus</i>		2	4	3	5	2	4	69.7

rows 7 (5-7); scales above lateral line 8 (7-10); scales below lateral line 22 (20-25); pored lateral line scales to hypural crease 70+2 on tail (67-72, Table 1); gill rakers 7+11 (18-20, Table 2); branchiostegal rays 6; vertebrae 10+14.

Measurements are given as per cent SL in Table 3; the following measurements are additionally presented as per cent HL: head depth 98% (98-108); snout length 39% (36-45); upper jaw 41% (37-43); lower jaw 48% (45-51); cheek depth 44% (39-47); opercular length 27% (24-29); snout to upper margin of preoperculum 77% (74-79); orbit diameter 26% (25-33); suborbital depth 23% (19-25).

TABLE 2
Frequency distribution of the number of first arch gill rakers in Branchiostegus wardi and B. serratus

		Gill Rakers (upper and lower limbs)						
		18	19	20	21	22	23	\bar{X}
<i>B. wardi</i>	19.9
<i>B. serratus</i>	18.6

Head blunt, snout steep, body elongate. Mouth oblique, upper jaw moderately protrusile; maxillary anteriorly reaching to below first nostril, posterior extension to below centre of pupil. Upper lip set in groove along entire edge; lower lip not grooved medially. Teeth on upper jaw in double bands, inner row of very fine canine teeth posteriorly, widening into four to five rows anteriorly; outer row of larger incurved canines with enlarged teeth

anteriorly and single large canine at extreme posterior margin of upper jaw. Lower jaw with fine canine teeth in patch on either side of symphysis; larger incurved canines in single row along outer jaw margin. No teeth on palatines, vomer or tongue; well-developed pharyngeal teeth.

Lateral line pores easily visible in low curve, passing slightly dorsal to middle of body bars and extending just past hypurals. Cephalic lateral line with five lower jaw pores from symphysis to preopercular margin, four-five pores in preorbital series, ten-twelve pores circumorbital, two pores below anterior nostril and one pore above posterior nostril; other cephalic pores present but not easily visible.

TABLE 3
Measurements of B. wardi and B. serratus in per cent standard length

	Holotype		<i>B. wardi</i>		Holotype		<i>B. serratus</i>	
	AMS IA. 5130	AMS IA. 5130	Specimen Ranges (n=18)	\bar{X}	AMS I.16207-004	AMS I.16207-004	Paratype Ranges (n=19)	\bar{X}
Standard length (mm)	..	327	215-336	263	285	213-405	267	
Body depth	26.0	22.6-26.1	24.57	26.1	24.6-27.7	26.77	
Body width	14.1	11.8-13.3	12.55	13.2	11.8-13.7	12.82	
Dorsal fin length	54.1	56.1-62.1	58.87	60.7	55.5-63.2	60.88	
Anal fin length	29.4	27.4-31.6	29.71	33.2	30.3-32.8	31.52	
Pectoral fin length	22.6	22.7-25.1	23.87	23.7	22.8-25.5	24.29	
Pelvic fin length	14.1	13.0-15.3	14.07	11.2	11.4-14.1	12.43	
Peduncle length	16.2	15.2-17.4	15.88	16.4	15.6-18.4	16.76	
Peduncle depth	11.6	10.0-14.2	10.88	11.4	10.3-11.9	11.01	
Head length	27.5	25.1-27.6	26.50	25.4	23.8-26.3	25.62	
Head depth	24.5	21.2-26.4	23.73	24.8	25.1-27.9	26.32	
Snout length	11.2	8.6-11.1	9.86	10.0	8.9-12.0	10.57	
Predorsal length	31.8	28.9-35.7	31.04	30.9	28.6-32.3	30.99	
Length of upper jaw	11.3	10.0-12.3	11.21	10.3	9.5-11.4	10.61	
Length of lower jaw	10.1	11.7-13.2	12.51	12.3	11.3-13.0	12.30	
Opercular length	7.7	6.9- 8.0	7.26	6.8	5.6- 7.3	6.51	
Diameter of orbit	5.7	5.8- 7.8	6.82	6.7	6.2- 8.5	6.97	
Cheek depth	11.3	9.1-11.0	10.13	11.1	9.4-11.8	10.86	
Suborbital depth	5.8	4.4- 5.7	5.07	5.8	4.6- 6.4	5.78	

Gill membranes free from isthmus and notched medially. Raised medial ridge on top of head from above posterior margin of orbit almost to dorsal origin. Anterior nostril within a thin cutaneous tube, posterior nostril open and oval shaped. Preopercular angle approximately 100-115°, with fine serrae on upper limb, less distinct serrae on lower limb. Operculum ending in single blunt spine or tab. Pseudobranch well developed; gill rakers blunt, generally three or more times longer than wide, although reduced toward distal ends of limbs.

Scales large, embedded in pockets, ctenoid over most of body, cycloid in head region; scales on cheek, operculum and extending on top of head to posterior margin of pupil. Scales on base of pectoral; caudal fin finely scaled, other fins naked; body with mostly regenerated scales.

Dorsal fin continuous, origin above pectoral bases; dorsal spines slender, first two close together, united at their bases and slightly shorter than remaining five spines; latter nearly equal in length and about $\frac{3}{4}$ length of anterior seven rays. Rays 8-12 about $\frac{1}{4}$ longer than anterior rays; ray 13 elongate, reaching just past hypurals and $\frac{1}{7}$ longer than next longest dorsal ray; rays 14 and 15 progressively shorter.

Anal fin continuous, origin below fourth dorsal ray; two anal spines slender and close together; first spine about $\frac{1}{2}$ length of second, second spine $\frac{1}{2}$ or less

length of anal rays. First three rays progressively longer, fourth ray about $\frac{4}{5}$ length of all but last two rays; penultimate anal ray elongate, reaching base of hypurals.

Pectoral fins pointed, with scaled bases; tip of fin reaching to level of anus; rays branched except stout first ray; length of first ray $\frac{1}{3}$ or less than longest pectoral ray. Pelvic fins rounded or slightly pointed, inserted below posterior margin of pectoral base and reaching to middle of pectorals. Caudal fin truncate, tips extended, dorsal tip longer than ventral tip; 17 principal and 15 branched rays; 11 dorsal and 10 ventral procurent caudal rays.

Colour of holotype silver-white with some overlying yellow-orange and 18 (18 or 19 in paratypes) dark blue-violet wedge-shaped bars; bars shorter anteriorly and posteriorly, each tapering to a point about in line with lower margin of orbit. Iris golden, black area on dorsal margin of orbit; cheeks silver-white with an oblique dark band reaching from preoperculum nearly to orbit; snout yellow-orange with black area on medial portion of upper lip; dorsal portion of head coloured as snout with overlying greyish hue, a raised yellow ridge on top of

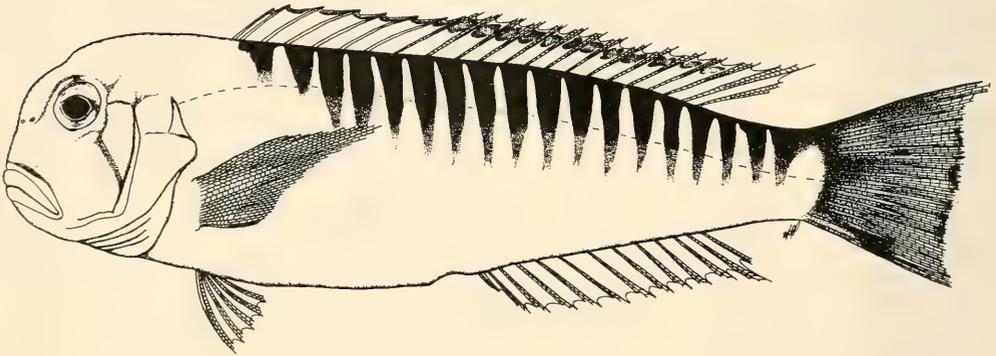


Fig. 1. *Branchiostegus serratus*.

head from vertical of posterior margin of orbit to near dorsal origin. Dorsal fin membrane dusky, spinous portion dusky with narrow yellow margin; some diffuse yellow in front of first ray and elliptical yellow spots along dorsal margin between each ray, decreasing between soft rays 8 and 9 and disappearing between rays 12 and 13; last ray dusky. Anal fin membrane translucent. Pectoral fin opaque with black edging on first and second rays. Pelvic fins translucent. Caudal fin base orange; central portion yellow with medial black area not reaching posterior margin; medial posterior margin edged in black, dorsal and anal lobes black (Fig. 1).

Distinguishing Features. Three species of *Branchiostegus* have a series of vertical dark body bars, *B. serratus*, *B. semifasciatus* from West Africa and *B. doliatus* from East Africa and Mauritius. *B. semifasciatus* has six dorsal spines (usually seven in *B. serratus*), 47–50 pored lateral line scales (67–72 in *B. serratus*), a dark head ridge and large dark area above the pectoral fin axillae and behind the dorsal margin of the operculum (both light in *B. serratus*). *B. doliatus* has six dorsal spines, 16–18 vertical body bars (18–19 in *B. serratus*), and a dark blotch on the operculum (none in *B. serratus*). The two Australian species can be distinguished by coloration, with *B. wardi* lacking vertical bars, pored lateral line scales (Table 1), and snout profile, with *B. serratus* having a steeper snout.

Etymology. The specific name is in reference to the series of dark body bars.

DISTRIBUTION AND BIOLOGY

Branchiostegus serratus is known only from the coast of New South Wales, where it is trawled from Coff's Harbour (30° 20' S) to Lake Illawarra (34° 30' S). The only recorded depth range is 110–150 m, from a State Fisheries trawl off Newcastle (33° S). The other Australian species, *B. wardi*, is known from Noosa Heads, southern Queensland (26° 25' S) to off Broken Bay, New South Wales (33° 30' S). A 410 mm specimen of this species was recently taken off the edge of a reef at 250 m off Noumea, New Caledonia (P. Fourmanoir, pers. comm.). Apparently both species are trawled in similar depths off New South Wales.

Fluctuations in the abundance of the North American tilefish *Lopholatilus chamaeleonticeps* have been well documented (Collins, 1884). The limited available evidence indicates that the Australian species may also undergo population fluctuations. *B. wardi* was first collected off Queensland in 1928 (Marshall, 1928) and a second specimen was trawled in 90–110 m off Port Stephens, New South Wales, in 1931 (Whitley, 1932). In 1972–73 from 50 to 300 kg of *B. wardi* per day were sent to the Sydney wholesale markets from the Newcastle-Port Stephens area. Fewer *B. serratus* arrived at the markets, from none to about 25 kg per day. Neither the *Thetis* Expedition of 1898, which trawled off Port Stephens–Newcastle in 60–100 m (Waite, 1899 : 20), nor the *Endeavour* Collections of 1909–1910, which were taken from 30–110 m off Port Stephens–Newcastle (McCulloch, 1911 : 3, 23), took any specimens of *Branchiostegus*. It is possible that both species are more abundant now than they were 60 or 70 years ago. However, this is impossible to verify since the amount of fish marketed in past years cannot be broken down by species ; moreover, methods of trawling have changed over the years, further making any comparison of numbers unreliable.

Stomach contents of 12 specimens of *B. wardi* and 7 specimens of *B. serratus* were examined. Both species are benthic carnivores, with remains of fish (*Apogonops anomalous*), molluscs (bivalves and gastropods), crustaceans (crabs, amphipods and stomatopods) and polychaetes in the stomachs and intestines of both species.

All of the type material of *B. serratus* proved to be mature. Selected market specimens of *B. wardi* (totalling 31) were dissected to determine the sex and reproductive state. A deviation from the expected 50/50 sex ratio was found both for *B. wardi* and for *B. serratus*. *B. wardi* specimens under 300 mm were predominantly females ; above 300 mm, only males were identified. Twenty-nine specimens of *B. serratus* were examined. Below 280 mm there were approximately equal numbers of males and females, but, as in *B. wardi*, only males were identified in the larger sizes. It can be hypothesised either that only males reach a larger size or that there is protogynous sex reversal. There is as yet no strong evidence for the latter hypothesis. Ovaries from specimens of *B. wardi* taken in June, July and September 1972 and in January 1973 were removed, preserved in 10% formal-saline and later dissected. The ovaries measured 35–50 mm in length and 10–20 mm in diameter ; ova of various sizes ranging from 0.2–0.8 mm in diameter were distributed evenly in the ovaries. No seasonal differences in gonad condition were noted. The range of ova size and the presence of large ova in all ovaries examined are indicative of multiple spawning during the year. The only ovaries of *B. serratus* examined were collected in June ; they were also filled with ova from 0.2–0.9 mm in diameter. The larvae, although unknown, would probably resemble those of *B. japonicus* (Okiyama, 1964). Larvae in four of the five tilefish genera (larvae of *Lopholatilus* are unknown) have been found to have similar arrangements of spinules and head serrations.

ACKNOWLEDGEMENTS

W. Brinsley, Fisheries Inspector at the Sydney Fish Markets, extended every courtesy in making available both specimens and information. T. Gorman and T. Johnson of N.S.W. State Fisheries provided specimens from FRV *Kapala*. P. Fourmanoir provided information on and a photograph of the Noumea specimen. B. Campbell (QM) and V. Springer (USNM) loaned specimens under their care. M. Peoples drew Fig. 1. J. Randall and B. Russell made suggestions on the manuscript. To all goes our appreciation.

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THE SYSTEMATIC AND PHYLOGENETIC POSITION OF
PALAEOSPONGILLA CHUBUTENSIS (PORIFERA : SPONGILLIDAE)

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[Accepted for publication 19th June 1974]

Synopsis

Palaeospongilla chubutensis Ott and Volkheimer (1972), the first fossil spongillid ever recorded, was detected during an examination of stromatolithic crusts of blue-green algae from lacustrine sediments of the Cretaceous of Patagonia. It is represented by a fully intact skeletal arrangement of megascleres and microscleres, both of two types, and also contains numerous gemmules with gemmoscleres *in situ*.

Based on a thorough reexamination of parts of the type material, which demonstrates the early perfection of gemmule-producing freshwater Demospongiae, the present study reveals additional criteria which are used to interpret more precisely the relationship of the Mesozoic fossil to extant genera and species. *P. chubutensis* displays gemmoscleral characteristics from which both acerate and birotulate spicular types could have evolved by divergence, and it is significant to find it the almost direct ancestral form of the extant genus *Radiospongilla* which has retained identical gemmular and gemmoscleral criteria and which today represents such a central stock. Furthermore, the fossil spongillid is obviously closely related to two additional extant genera, i.e. *Spongilla* and *Pectispongilla*, which also share some of its structural characteristics.

Recent advances in the fields of palaeolimnology, plate tectonics, and continental drift provide a feasible background for speculation on spongillid evolution, dispersal routes and distribution since the occurrence of the Patagonian fossil, some 100 million years ago.

INTRODUCTION

The discovery of extensive fully fossilised crusts of the spongillid *Palaeospongilla chubutensis* in lacustrine sediments of the Cretaceous in the Chubut River Valley of Patagonia, by Ott and Volkheimer (1972), can only be described as exciting. Although spicular remains of freshwater Porifera, mostly comparable with those of extant genera and species, have been recorded from a number of lentic sediments of Tertiary age (Traxler, 1895, 1896; Reul, 1954; Racek, 1966, 1969, 1970), no palaeontological evidence could hitherto be obtained for Mesozoic occurrences of gemmule-producing freshwater Demospongiae, nor was it considered likely that a well-preserved spongillid fossil could ever be found. Factors preventing successful fossilisation of freshwater sponges would seem to include both their comparatively flimsy skeleton, and, in particular, the established rapid deterioration of their symplasm after death. The exceptionally perfect preservation of *P. chubutensis*, over a period of more than 100 million years, can thus only be explained by the fact that its entire surface was rapidly covered by a thick layer of calcareous algae (Cyanophyceae) which smothered the sponge itself and simultaneously prevented it from being crushed during sedimentation.

Realising the uniqueness of their unexpected discovery, made during a routine examination of stromatolithic crusts of blue-green algae, Ott and Volkheimer (1972) proceeded with the description of *P. chubutensis*, which they rightly considered generically and specifically different from any extant spongillid hitherto recorded. However, in spite of the clarity and morphometric accuracy of the original description, the present authors considered it imperative to reexamine parts of the type material in order to attempt a reliable assessment of the fossil's systematic and phylogenetic position in line with the recent comprehensive revision of Penney and Racek (1968), which was unavailable to the describing palaeobotanists. This reexamination, made possible by courtesy

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of Dr. E. Ott, revealed additional information of multidisciplinary significance, which enabled the present authors to solve a number of problems previously encountered.

MATERIAL AND METHODS

The fossilised remains of *P. chubutensis*, used for this study, consisted of three slides containing thinly ground sections of a topotype, i.e. material adjoining that selected as a holotype by Ott and Volkheimer. Although these sections permitted most useful general observations, and were at least as informative as the slides used for the original description of the sponge, it became necessary to separate the various spicules from the rocky matrix so that their detailed structures could be thoroughly examined. This was first achieved by removing the mounting medium of the slides with xylene and acetone, after which the matrix was treated with boiling nitric acid in order to dissolve all non-siliceous matter and to reveal the structural characteristics of the spicules. The illustrations for this paper were prepared from photomicrographs and camera lucida drawings, using a Zeiss-Winkel microscope and its accessories.

REVISED MORPHOLOGICAL EVALUATIONS

Palaeospongilla chubutensis Ott and Volkheimer, 1972, pp. 49–63.

Holotype. Three sections and one polished rest-cut of the branch holding the sponge incrustation, in the collections of the Museo Argentino de Ciencias Naturales "B. Rivadavia", Buenos Aires.

Topotype (selected by the present authors). Three sections from another part of the fossil, of which one was fully dissolved in nitric acid, resulting in several spicule slides; material deposited in part in the collections of the Australian Museum, Sydney, and in part in those of the Smithsonian Institution, U.S. National Museum, Washington, D.C.

Type locality. Creaceous lacustrine sediments of the Chubut Group, Valley of the Río Chubut, 16 km NNW of Cerro Condor, Patagonia, Argentina.

Distribution. Hitherto known only from the type locality.

Redescription. Sponge encrusting the fossilised remains of what appears to be a gymnosperm stem or root, in cushions from 2 to 6 mm in thickness, and surrounded by a rather thick layer of covering calcareous algae (Cyanophyceae). Skeleton forming several clearly defined tiers of megascleres, displaying a well-arranged and rather regular meshwork of vertical and horizontal spicule fibres, indicating the original presence of a considerable amount of binding spongin. Spicule fibres consisting of joined bundles of up to 40 megascleres, forming meshes of about 1000 μm in diameter. Original surface of sponge difficult to assess since the surrounding thick crust of calcareous algae adjoins very closely.

Megascleres of two distinct types, both feebly curved or almost straight. The much more common type A represented by rather stout and almost cylindrical amphioxea, as a rule completely smooth, occasionally bearing one or two irregular smaller spines without characteristic arrangement or position (Fig. 1a). Length range 420–540 μm , width range 10–22 μm . Megascleres of type B less prevalent in the preparations made, smaller and more slender, typically fusiform with rather sharp apices, armed with inconspicuous spines except at their tips (Fig. 1b). Length range 180–308 μm , width range 4–14 μm . Megascleres of type A forming the main skeleton of basal and central parts of the sponge, those of type B associated more with peripheral spicule fibres.

Free microscleres (Fleischnadeln), like the megascleres, of two distinct types, both almost straight or only very slightly curved amphioxea with distinctly sharp apices. The much more common type A represented by rather long and

slender scleres, incipiently to conspicuously spined along almost their entire length (Fig. 1c). Length range 179–190 μm (partly assessed from fragments), width range 3–4 μm , spines rarely exceeding 1 μm in height. Microscleres of type B somewhat smaller and entirely smooth amphioxea (Fig. 1d). Length range 77–147 μm (partly assessed from fragments), width range 3–5 μm . Both types seem not to be indicative of a certain position in the sponge, although they appear more abundant above the layer of gemmules.

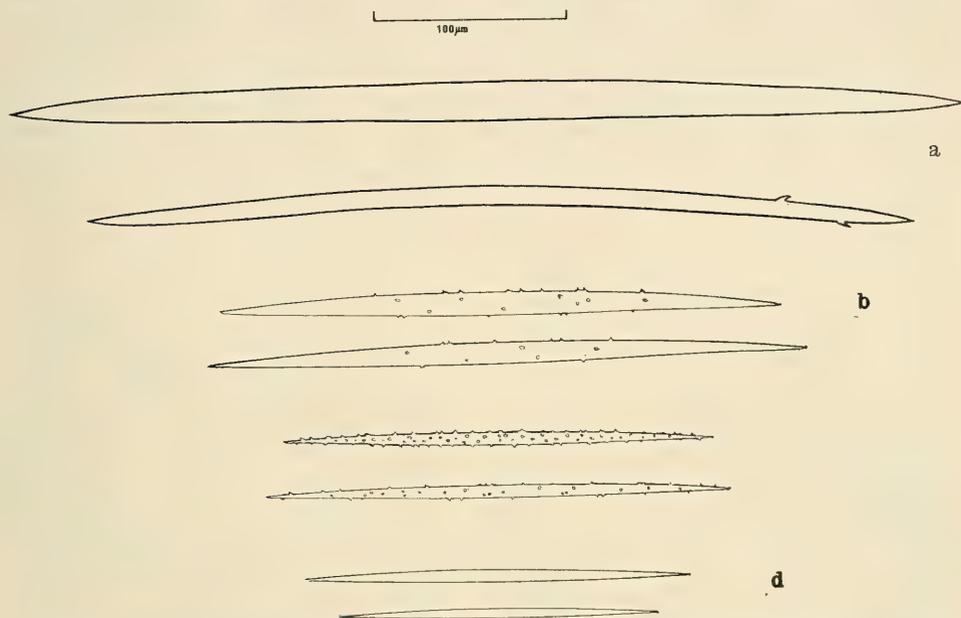


Fig. 1. *Palaeospongilla chubutensis*. a. Range of megascleres of type A. b. Range of megascleres of type B. c. Range of microscleres of type A. d. Range of microscleres of type B.

Gemmoscleres moderately long and slender amphistrongyla, often possessing a spine in the prolongation of their axis so that they appear amphioxeous. They are armed with numerous acute spines along their entire shaft, while in the vicinity of the extremities of the sclere these spines are distinctly aggregated, often forming sceptre-like distal arrangements of perceptibly recurved teeth (Fig. 2a). Pseudorotules could not be observed. Length range of gemmoscleres, which are only slightly curved, 77–168 μm , width range 3.5–6 μm .

Gemmules quite abundantly produced, not confined to base of sponge but instead freely scattered through skeletal meshwork. Although they are generally spherical, ranging in diameter 490–570 μm , their thick and well-developed pneumatic coat is of irregular height, varying from 63 to 95 μm (Fig. 2b). Gemmoscleres embedded in this coat more or less radially but mostly crossing each other at various angles, arranged in one layer only, their distal extremities not appreciably penetrating the outer gemmular membrane. None of the sections available displayed a cut through the region of the micropyle; thus foraminal structures remain unknown.

Discussion. Ott and Volkheimer (1972), the discoverers of this first spongillid known from the Mesozoicum, provided a very useful general description and carefully assessed measurements of the variety of spicular components. However, some of their morphological evaluations must now be amended. Since

they had no access to recent taxonomic revisions (Penney and Racek, 1968; Racek, 1969, 1970), which include data from subfossil spicular remains, and based their description on the study of thin sections only, it is understandable that they faced difficulties in expressing the status of some scleral components. While the megascleres of type A, including those which possess a small number of irregular spines, were correctly observed, the spined type B were not recognised as megascleres, but were instead included in the range of occurring free microscleres, thus indicating a greater average length of the latter. The assessment of all scleres from sections, the matrix of which grossly distorts the

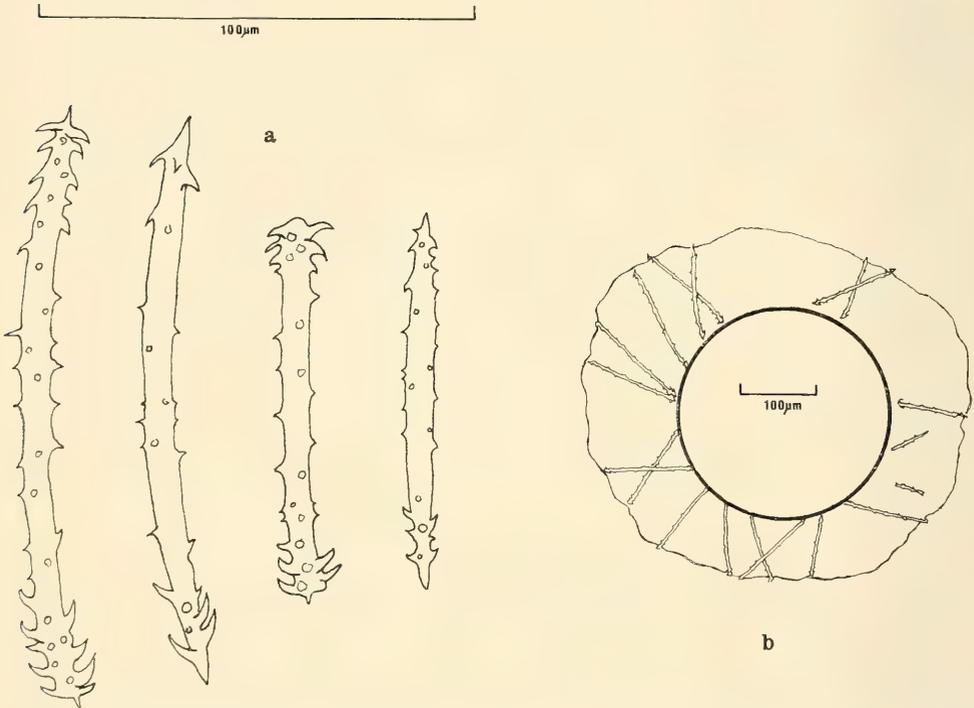


Fig. 2. *Palaeospongilla chubutensis*. a. Range of gemmoscleres. b. Section through fossilised gemmule, with gemmoscleres *in situ*.

characteristics of the spicules, seems to have resulted in somewhat misleading line drawings, which show little resemblance to those scleres illustrated in the excellent photomicrographs of the original description. Following the isolation, by the present authors, of spicular components from the matrix, it can now be established that there are two types of both megascleres and microscleres, a condition which has not been retained in any extant genus of the now redundant subfamily Spongillinae Vejdovsky, i.e. those spongillids possessing acerate (non-birotulate) gemmoscleres. The possibility of a spicular mixture of two distinct species, both fossilised simultaneously, can be readily dismissed. Although such a condition can occasionally be observed in living spongillids (usually a result of competition for a restricted substrate), there is always evidence of growth overlap, i.e. two distinctly separated skeletal floors, each displaying the spicular characteristics of one of the adjoining or overgrowing spongillids involved. The careful examination of the skeletal arrangement of *P. chubutensis* did not reveal such a condition and demonstrated beyond doubt that the spicular components of the fossil belong to a single species. Both types of megascleres take part in

the construction of a rather uniform skeleton, uninterrupted by membranes, tiers or floors. The free microscleres of both types occur side by side throughout the quite insignificant height of the sponge crust, without any indicative position. The typical gemmules are not restricted to either the upper or lower portion of the flat sponge growth but are scattered throughout the skeletal meshwork. No other types of gemmules nor even single gemmoscleres of any other species could be observed in the material available.

Considering all the morphological characteristics of *P. chubutensis*, as reexamined by the present authors, and in spite of the close affinities of both gemmules and gemmoscleres of the fossil sponge with those occurring in a number of species of the recent genus *Radiospongilla* Penney and Racek (Fig. 3a-g), the choice of a new genus for this Mesozoic spongillid by the describing authors is fully supported by the present work. In the following section, the fossil sponge's systematic and phylogenetic position will be discussed in the light of recent taxonomic, ecological and geological studies.

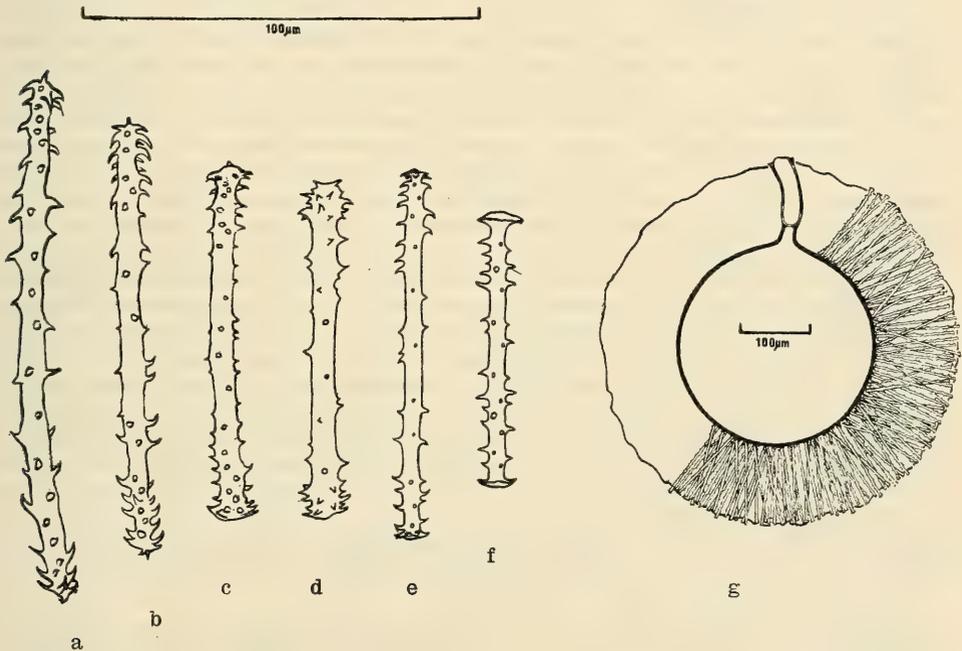


Fig. 3. Morphological features of extant *Radiospongilla* spp. gemmoscleres. a. *R. cerebellata*. b. *R. philippinensis*. c. *R. hemephydata*. d. *R. sceptroides*. e. *R. crateriformis*. f. *R. cantonensis*. g. Optical section through gemmule of *R. cerebellata* (left half of gemmoscleres omitted).

SYSTEMATIC, PHYLOGENETIC AND ECOLOGICAL EVALUATIONS

Penney and Racek (1968), by introducing a new genus, *Radiospongilla*, as a natural morphological link between the spongillids with acerate and those with birotulate gemmoscleres, demonstrated the fallacy of the previously widely applied division of the family Spongillidae into the meaningless subfamilies Spongillinae and Meyeninae. Although lacking fossil evidence, Penney and Racek suggested that the two different types of gemmoscleres present in these artificial subfamilies had resulted from divergence from shapes originally present in an hypothetical stock, from which the extant genus *Radiospongilla* could also

have evolved. While most species of *Radiospongilla* possess distinctly acerate gemmoscleres, whether of amphioxeous or amphistrongyloous shape, they are characteristic in having terminal aggregations of gemmoscleral spines, often forming pseudorotules. One of these species, i.e. *R. cantonensis* (Gee) (Fig. 3f), produces almost perfect birotulate gemmoscleres which are straight and therefore strictly radially arranged, thus documenting the likelihood of a gradual evolutionary divergence of both acerate and birotulate spicules from scleres present in an ancestor, from which both these types could have been derived. The antiquity of the extant genus *Radiospongilla* has now been established by palaeolimnological examinations of Pliocene and Pleistocene sediments (Racek, 1969) and there is no doubt that this genus occupies a central phylogenetic position. However, what could have been more gratifying than to obtain palaeontological evidence of the existence of an even earlier spongillid, which clearly displays ancient traits from which both acerate and birotulate gemmoscleres could have arisen?

As can be expected from a fossil of about 100 million years of age, *P. chubutensis* differs in several ways from any presently living genus or species. It thus deserves a taxonomic status of its own, at generic as well as specific level, although lying close to *Radiospongilla*. At the same time, the Mesozoic fossil displays spicular and constructional criteria which are now found separately in species of three extant genera, i.e. *Radiospongilla*, *Spongilla*, and *Pectispongilla*. With *Radiospongilla* the fossil shares almost unchanged gemmular and gemmoscleral characteristics and at least one type of megascleres, i.e. those which are incipiently spined, but differs by the presence of free microscleres, which are typically absent in *Radiospongilla*. *Spongilla*, too, seems to have inherited some of the characteristics of *P. chubutensis*. These are in particular the flesh spicules, of which only the spined type is retained in *Spongilla*, and also the cylindrical shape of the smooth megascleres. Even though *Spongilla* must be considered more distantly related to the fossil than *Radiospongilla*, especially with respect to gemmular and gemmoscleral structure and shape, its evolution from this ancestral type is most likely. *Pectispongilla*, an extant genus closely related to *Radiospongilla*, usually possesses two types of flesh spicules, and thus shares an apparently important morphological criterion with *P. chubutensis*. *Pectispongilla*, in addition, displays a similar skeletal construction and rather insignificant depths of encrustations. However, although the gemmoscleres are inserted in a manner similar to that both in *P. chubutensis*, and in almost all *Radiospongilla* spp., the gemmules of *Pectispongilla* are much smaller, lack the thick pneumatic coat, and their gemmoscleres display a unique and specialised arrangement of mostly unilateral spines.

As with all fossil evidence, the phylogenetic relationship of the Cretaceous spongillid to living forms can only be assumed until earlier ancestors are found. However, the above comparison of combined characteristics displayed by *P. chubutensis* with those found separately in the three extant genera makes it more feasible to speculate about the possible pathway of spongillid evolution during the past 100 million years, both chronologically and spatially. The fossil clearly demonstrates the early existence of perfected gemmule-producing sponges in inland waters, long before the isolation of non-spongillid Porifera of rather marine facies in the so-called "ancient freshwater lakes". Recent comprehensive studies by the present authors of a great number of gemmule-less Porifera from a range of thalassoid environments (Racek; Racek and Harrison, unpublished data) show conclusively that they must have arisen not only from different ancestors but also in much more recent geological times. The polyphyletic origin of the "freshwater sponges", already assumed by Marshall (1883), commented on by Penney and Racek (1968) and Racek (1969), and discussed by Brien (1966a, 1966b, 1969, 1973), has thus become well documented.

Until recently, morphological comparisons between fossilised presumed ancestral stocks and extant related organisms were the only means of assessing evolutionary pathways. However, recent continental drift reconstructions from plate tectonics (Oxburgh, 1971; Smith, 1971; Vine, 1971) can now be used to demonstrate feasible pathways of dispersal and speciation leading from the Mesozoic fossil of Patagonia to related extant groups of spongillids. Since *P. chubutensis* can be recognised as the almost direct ancestral form of the genus *Radiospongilla* in general, and of the *R. cerebellata* group in particular, the present distribution of these essentially southern sponges suggests an evolutionary pathway following a west-east course along the Mesozoic continuity of the combined landmass of parts of South America, Antarctica and Australasia as one route, and along southern Africa and the then connected Indo-Pakistani subcontinent as another. That this is not an isolated case can best be demonstrated by the present range of two different extant spongillids, i.e. *Spongilla alba* and the *Ephydatia ramsayi* complex (Penney and Racek, 1968). While both these extant spongillids display a markedly uniform morphology over their entire range from South America through Australia to at least south-eastern Asia, *S. alba* shows drastic speciation trends from South America northward (*S. cenota* in central America, and *S. wagneri* in the southeastern United States), whereas some distant relatives of the *E. ramsayi* complex (i.e. *E. robusta* and *E. subdivisa*) are not represented south of the United States. Since it has been established (Fooden, 1972) that Australia must have separated from the Antarctic plate some 45–50 million years ago, it is obvious that both *S. alba* and the *E. ramsayi* complex must have existed long before the final dismemberment of "Gondwanaland". On the other hand, clear speciation trends, and even discontinuity, seem to have occurred along the distributional pathway from South America northward, indicating the earlier existence of major distributional barriers, and ensuing isolation of sponge populations. Another indication of such a development is the absence of the *R. cerebellata* group of sponges, one of the closest descendants of *P. chubutensis*, north of Brasil. In spite of recent detailed studies by specialists in South America, none of the species of the above group have hitherto been recorded from that area, although some more remotely related species are known to range discontinuously from central Argentina Bonetto and Ezcurra, 1964) through Mexico to the United States (Penney and Racek, 1968).

While the evolutionary pathway leading from the Mesozoic fossil to those few most closely related species of *Radiospongilla* now seems well documented, the rise of the extant genus *Spongilla* is more difficult to assume. It consists today of two groups of species, both markedly different in morphological characteristics, ecological preferences and, last but not least, zoogeographic distribution. The *S. alba* complex, already discussed above, must be considered another close relative of *P. chubutensis*, and has a distinct southern distribution and a pronounced preference for alkaline habitats. The geologically more recent *S. lacustris* group appears to be another evolutionary line. It is presently restricted to the Northern Hemisphere, and occurs in acidic to only slightly alkaline lentic and lotic habitats. Although the general morphological criteria within *Spongilla*, as restricted by Penney and Racek (1968), are fairly constant, and certainly generically characteristic, the possibility that these two groups arose separately and at different geological periods cannot be dismissed. Until further fossil spongillids are found, particularly in northern landmasses of the past, any definite conclusions as to the ancestry of the extant genus *Spongilla* s.s. must remain strictly speculative.

In dealing with presumed pathways of evolution and speciation, one naturally has to consider possible dispersal routes. In the family Spongillidae, these do

not necessarily require fully connected landmasses, since their gemmules are well known to be distributed by aquatic birds. This often occurs over considerable distances, including extensive stretches of oceans, with occasional dispersal by wind from dried water beds. While such an indirect dispersal could possibly have accounted for the advance of certain spongillid groups from Australia to nearby Asia, or vice versa, the unlikely presence either of true birds or of any other animals capable of intercontinental flight at the time of the occurrence of *P. chubutensis* would seem to rule out such a possibility. Considering all the factors discussed, therefore, the evolutionary advance from the Patagonian fossil to at least those species of *Radiospongilla* which have retained identical gemmular and gemmoscleral structures and characteristics, and which today abound in Australia, Africa and S.E. Asia, can only be suggested to have taken a west-east course prior to the dismemberment of "Gondwanaland", which would have permanently disrupted such an advance. In the light of this new evidence, the previously held belief that some of the Australian spongillid fauna is a mere southward extension of that of Asia (Racek, 1969), seems severely affected. It is now most feasible to believe that such an advance to both these continents occurred independently, and that any later exchange of certain species from one to the other has been a mutual one.

With respect to ecological evaluations of the probable physical, chemical and climatic conditions present during the occurrence of *P. chubutensis* in the Cretaceous, those characteristic for related *Radiospongilla* spp. may be used for comparison. Both the *R. cerebellata* group of species, and to a certain extent also *R. hemephydatia*, are essentially tropical species. Their conspicuously thick pneumatic coat with its gemmoscleral armature, identical with that found in *P. chubutensis*, is indicative of hot or even arid climates. The two *Radiospongilla* spp. compared above prefer lentic habitats or still backwaters of the lotic series. They furthermore appear to prefer distinctly alkaline conditions in their optimal habitat and show little tolerance of sharp falls in hydrogen-ion concentrations. The thickness of the gemmular pneumatic coat and its dense gemmoscleral armature point to a warm to very warm, and perhaps even arid, climate during the life of the Patagonian fossil in the Cretaceous. Its habitat undoubtedly belonged to the lentic series, as already suggested by Ott and Volkheimer (1972). And the fact that its natural environment must have been strongly alkaline is demonstrated by the abundant, and apparently rapid, growth of the surrounding calcareous algae, as well as by the actual mode of fossilisation.

ZUSAMMENFASSUNG

Der Fund des ersten fossilen Spongilliden, *Palaeospongilla chubutensis* Ott and Volkheimer (1972), aus der Kreide Patagoniens offenbarte interessante morphologische Strukturen, die gründliche systematische und phylogenetische Studien erforderten. Dieses guterhaltene Fossil aus lakustrinen Sedimenten, etwa 100 Millionen Jahre alt, besteht aus zusammenhängenden Skelettfasern von Megaskleren und freien Fleischnadeln, beide vertreten mit zwei verschiedenen Typen. Es enthält ausserdem eine grosse Anzahl von Gemmulae mit deren Belagsnadeln, *in situ*. Die vorliegende Neuuntersuchung dieses mesozoischen Spongilliden warf neues Licht auf die Annahme einer frühen Abzweigung der Gemmulae-erzeugenden Süsswasserschwämme von deren "marinen" Vorfahren. Diese Arbeit beweist, dass *P. chubutensis* als Ahnform dreier rezenten Gattungen, d.i. *Radiospongilla* Penney and Racek, *Spongilla* Lamarck, und *Pectispongilla* Annandale anzusehen ist, da sie kombinierte Nadelformen besitzt, die in den oben genannten Gattungen separat vorkommen, obwohl das Fossil der Gattung *Radiospongilla* am nächsten steht. Die Ergebnisse dieser Untersuchung sind von besonderer phylogenetischer Bedeutung, da sie auf die Abzweigung der früher anerkannten Unterfamilien Spongillinae Vejdovsky und Meyeninae

Vejdovsky von einem zentralen Ahnenstamm hinweisen, der heute durch die spezialisierten Arten der Gattung *Radiospongilla* repräsentiert wird.

Gegenwärtige Fortschritte in den Gebieten der Palaeolimnologie, Plattentektonik, und Kontinentverschiebung werden dazu verwertet, um genauere Unterlagen für die Annahme phylogenetischer Verwandtschaftsverhältnisse zu erhalten, und auch die heutige zoogeographische Verbreitung rezenter Arten zu erklären. Es wird ausserdem versucht, die physikalischen, chemischen, und klimatischen Verhältnisse während des Vorkommens des mesozoischen Fossils zu erklären.

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Reprints

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MUTAGENIC EFFECTS OF ETHYL METHANESULPHONATE ON THE OAT STEM RUST PATHOGEN (*Puccinia graminis* f. sp. *avenae*)

C. TEO* AND E. P. BAKER*

(Plate VII)

[Accepted for publication 17th April 1974]

Synopsis

Ethyl methanesulphonate (EMS) induced a high degree of stable variability in the dikaryotic uredial stage of the oat stem rust fungus (*Puccinia graminis* f. sp. *avenae*). Traits affected were uredospore colour, interval between uredial stage and subsequent telial development, virulence and pathogenicity. Mutations for virulence were induced on the oat cultivar Saia. Increases in mutagen concentration, duration of treatment and temperature during treatment significantly increased mutation rates. Recurrent mutagenic treatment increased mutation frequency and in addition produced a wider spectrum of mutants. Potential uses of mutants induced by EMS are indicated.

INTRODUCTION

Ethyl methanesulphonate (EMS) causes mutations in the dikaryotic uredial stage of the oat stem rust fungus, *Puccinia graminis* f. sp. *avenae* Eriks. and Henn. (Baker and Teo, 1966). In their studies aberrant uredospore colour and rapid telial-forming variants were described. The present studies provide estimates of mutation rates for these traits, and describe the effects of mutagen concentration, duration of treatment and temperature during treatment on mutation rates. In addition, alterations in virulence and changes in certain pathogenic traits were demonstrated.

MATERIALS AND METHODS

The strains of oat rust used were 2-0, 7-H and 8-H, the cultures of which are designated as BC1, BC2 and BC3, respectively, in the University of Sydney Rust Accession Register. Infection types produced on the oat differential varieties when inoculated with these cultures are shown in Table 1.

TABLE 1

Infection types exhibited on seedlings of various oat cultivars (resistance gene(s) in brackets) by three cultures of oat stem rust at $17 \pm 2^\circ\text{C}$

Cultivar	Rust culture		
	BC1	BC2	BC3
(a) Canadian differentials			
Richland, *08 (A)	1+	1	4
Rodney, 0654 (B)	2—	1—	1
White Tartar, 05 (D)	2= 2—	4	2—
Jostrain, 0617 (E)	3+	4	4
Eagle ² × C.I.4023, 0658 (F)	2= 2—	2	2—
C.I.5844·1, 0661 (H)	2= 2— 3c	3	3
(b) Supplementary differentials			
Minnesota Ag.331, 0615 (A D)	1+	1+	2—
Saia, 0589 (Sa)	; 1	; 1	; 1
Strain designation	2†-0†	7-H	8-H
Virulence formula (Green, 1963)	ABDFH/E§	ABF/DEH	BDF/AEH

* 0 numbers refer to Sydney University Oat Accession Register.

† Race designation according to Newton and Johnson (1944).

‡ The symbol 0 indicates avirulence on genes A, B, D, F and H. The symbol H indicates virulence on gene H.

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Seedling infection types, recorded 14–16 days after inoculation, were designated in accordance with the scale suggested by Stakman *et al.* (1923).

The oat cultivars employed were Bond and Saia. Bond is a susceptible hexaploid cultivar. Saia (an accession of *Avena strigosa* Schreb., a diploid species) is resistant to most oat stem rust strains in Australia. However, certain field isolates collected in eastern Australia (Luig and Baker, 1973) have proved virulent on this cultivar.

The current experiments were conducted to study, in part, the effect of mutagen concentration, duration of treatment, and temperature during treatment, on mutation rate for certain rust characters. In this regard culture BC2 was treated as follows:

1. With 9.8×10^{-2} , 14.7×10^{-2} and 19.6×10^{-2} M aqueous solutions of EMS for 2.0 hrs at 25°C. Distilled water was used in the preparation of the solutions. (M.W. of EMS is 124.16 and its density at 20°C was determined to be 1.2175).
2. For 2.0, 3.5 and 5.4 hrs with a 9.8×10^{-2} M solution at 20°C in separate experiments.
3. At 20, 25 and 30°C for 2.0 hrs with a 9.8×10^{-2} M solution.

Cultures BC1 and BC3 were also treated with EMS, each with a 14.7×10^{-2} M solution for 2.0 hrs at 20°C. Finally, the effect of treating an EMS-induced grey-brown uredospore colour mutant of culture BC2 with 12.5×10^{-2} M EMS solution for 2.0 hrs at 22°C was studied.

In recurrent mutagenic treatments cultures BC1 and BC2 were used. The former was treated for four and the latter for five successive uredial generations with 14.7×10^{-2} M EMS for 2.0 hrs at room temperature. Cultures BC1 and BC2 were also treated for two and three consecutive uredial generations, respectively, with 15.7×10^{-2} M EMS for 2.0 hrs at room temperatures in attempts to induce mutations for virulence on the cultivar Saia.

Uredospores were treated with solutions of EMS (100 mls per 0.2g of spores) in a stoppered flask shaken with a Griffin flask shaker. After treatment, the spores were rapidly filtered in a Buchner filtering apparatus. After washing, filtering was continued to remove as much water as possible from the spore mass. A sample was retained for assessment of spore viability. The remainder was dispersed in "Mobil Sol 100" (Rowell and Olien, 1957) and the suspension immediately sprayed with a "Desaga Spray Can" atomiser onto primary leaves of 1,500–2,000 seedlings of Bond. However, in experiments designed to induce mutations for virulence, 1,500–2,000 seedlings of Saia and 300 seedlings of Bond (to provide inoculum for the next recurrent mutagenic treatment) were inoculated simultaneously. A control experiment set up in each case comprised 500–600 seedlings of the appropriate cultivar inoculated with untreated spore samples. Inoculated plants were placed in misting chambers for 12–24 hrs and then transferred to well-lit glasshouse benches.

Assessment of Spore Germination

Samples of mutagen-treated and untreated spores were spread lightly and evenly on 2% water-agar in three petri dishes and placed in an incubator at 18–20°C for 24 hours. After this period, germination of at least 500 spores per dish was examined. The percentage spore germination was determined after totalling the results for each dish.

Spores were classified as inviable if no germination was shown or if initial germination occurred but germ tubes failed to continue growth. In the latter the germ tube barely appeared through a pore in the wall after 24 hours whereas germ tubes from viable spores showed extensive hyphal development after the same period.

Assessment of Mutation Rate

All leaves were examined and the number of mutants recorded. The total number of pustules appearing on all leaves was then counted. In certain experiments, where indicated, the total number of pustules was assessed by sampling. In these instances, the number of pustules on seedlings in ten randomly selected pots (approximately 35 seedlings per pot) was counted and the approximate total number of pustules in the experiment estimated on the basis of such sampling. This method of estimation was less reliable as the rate of infection varied somewhat from pot to pot. However, slight inaccuracies in the estimation of the total number of pustules by sampling were shown to have no significant effect on statistical assessment of mutation rate.

EXPERIMENTAL RESULTS

Induction of Mutants

During the course of various experiments spore viability following EMS treatments under similar conditions was found to vary markedly depending on the source and batch of the chemical. For example, spore viability ranged from 0–96% of controls (which showed 85–92% viability) after treatment with 9.8×10^{-2} M solutions for 2.0 hrs at 20°C in different experiments. Apparently EMS may contain impurities, such as mercapto ethanol, which are fungicidal, thus presumably accounting for reduced spore viability, the variation in which may have been due to relative amounts of impurities.

It was not possible to obtain EMS free from impurities on all occasions. Consequently, the use of EMS from sources which did not result in undue lethality offered the only practical solution to this problem. In experiments where strict comparisons were necessary, as in studies concerned with the effect of treatment variables, EMS relatively free from impurities and from the same bottle was used in all treatments.

Within the range of reduction in spore viability tolerated there was no evidence that impurities affected either the mutation rate or the type of mutants.

The influence of treatment conditions on spore viability and mutation rate in culture BC2 is recorded in Table 2. Spore viability decreased with increases in the mutagen concentration, duration of treatment and temperature during treatment. Conversely, the total mutation rate (which was based on both aberrant colour mutants and rapid telial-forming variants) significantly increased with increases in mutagen concentration, duration of treatment and temperature during treatment. A similar result was obtained when the rate of colour mutants alone was considered. In the case of rapid telial-forming variants increases in rate were significant only in instances where the 95% limits of expectation (calculated by the method of Stevens (1972)) did not overlap.

Two alternatives for determining mutation rates can be considered. The mutation rate can be estimated in terms of the total number of spores treated or in relation to the total number of spores which germinated and produced pustules. For practical considerations the latter estimate was used in these studies.

As with culture BC2, yellow and orange colour mutants and rapid telial-forming variants were readily induced in cultures BC1 and BC3 (Table 3). Mutation rates for these traits in the three strains did not differ significantly. No mutants were observed in the control experiments.

The results of recurrent mutagenic treatments of cultures BC1 and BC2 are shown in Table 4. With each successive cycle statistically significant increases in total mutation rate occurred. Moreover, a wider range of aberrant uredospore colour types was obtained. Grey-brown colour mutants, which were not obtained following single mutagenic treatment except on one occasion at the highest

TABLE 2
Effect of concentration, duration and temperature of EMS treatments on uredospore viability and mutation rate in culture BC2 of oat stem rust

Treatment	Spore viability (% control)	Total number pustules	Uredospore colour mutants			Rapid telial-forming variants			Total mutants							
			Yellow and orange no.	Grey-brown no.	Total no.	Mutation rate and 95% limits ($\times 10^{-3}$)			No.	Mutation rate and 95% limits ($\times 10^{-4}$)						
						O*	L	U		O	L	U				
2.0 hrs, 25°C	9.8 × 10 ⁻² M	11,724	60	—	60	5.12	3.91	6.58	2	1.71	0.22	4.24	62	5.29	4.06	6.78
	14.7 × 10 ⁻² M	5,592	57	—	57	10.19	7.73	13.19	5	8.94	2.90	20.87	62	11.09	8.51	14.21
	19.6 × 10 ⁻² M	31,949	556	3	559	17.50	16.09	19.00	42	13.15	9.48	17.78	601	18.81	17.35	20.36
9.8 × 10 ⁻² M, 20°C	2.0 hrs	14,092	28	—	28	1.99	1.32	2.81	2	1.42	0.18	3.53	30	2.13	1.44	3.04
	3.5 hrs	12,319	65	—	65	5.28	4.07	6.72	5	4.06	1.31	9.47	70	5.68	4.43	7.18
	5.4 hrs	16,964	187	—	187	11.02	9.51	12.12	9	5.30	2.43	10.07	196	11.55	10.00	13.28
9.8 × 10 ⁻² M, 2.0 hrs	20°C	10,413	22	—	22	2.11	1.32	3.20	2	1.92	0.23	6.93	24	2.30	1.49	3.43
	25°C	12,741	72	—	72	5.65	4.40	7.13	4	3.14	0.85	8.04	76	5.96	4.70	7.46
	30°C	10,373	126	—	126	12.15	10.13	14.45	11	10.60	5.29	18.97	137	13.21	11.09	15.61

* O = Observed ; L = Lower limit ; U = Upper limit.

TABLE 3
Comparative effects of similar mutagenic treatments on uredospore viability and mutation rates in three cultures of oat stem rust

Treatment	Rust culture (% control)	Spore viability number pustules	Total number pustules	Yellow and orange uredospore colour mutants			Rapid telial-forming variants			Total mutants					
				No.	Mutation rate and 95% limits ($\times 10^{-3}$)			No.	Mutation rate and 95% limits ($\times 10^{-4}$)			No.	Mutation rate and 95% limits ($\times 10^{-3}$)		
					O*	L	U		O	L	U		O	L	U
14.7 × 10 ⁻² M EMS, 2.0 hrs 20 ± 1°C	BC1	50.2	12,613	38	3.01	2.13	4.13	9	7.13	3.27	13.54	47	3.73	2.74	4.95
				63	4.19	3.22	5.35	8	5.31	2.29	10.47	71	4.72	3.69	5.95
				22	3.21	2.02	4.86	6	8.77	3.21	19.08	28	4.09	2.72	4.74

* O = Observed ; L = Lower limit ; U = Upper limit.

Rust culture	Treatment	Recurrent cycle number	Spore viability (% control)	Total number pustules	Uredospore colour			
					Yellow and orange no.	Grey-brown no.	Total no.	
BC1	14.7 × 10 ⁻² M, 2.0 hrs	20 ± 1°C	Initial	50.2	12,163	38	—	38
		22 ± 1°C	1	38.2	11,353	90	—	90
		22 ± 1°C	2	45.8	8,917	157	3	160
		19 ± 1°C	3	57.1	7,688	244	4	248
BC2	14.7 × 10 ⁻² M, 2.0 hrs	20 ± 1°C	Initial	47.5	15,050	63	—	63
		21 ± 1°C	1	43.4	11,439	118	2	120
		19 ± 1°C	2	59.6	7,302	109	5	114
		22 ± 1°C	3	37.7	10,725	329	3	332
		19 ± 1°C	4	53.4	8,120	416	7	423

* O = Observed ; L = Lower limit ; U = Upper limit.

EMS concentration (Table 2), were readily induced following recurrent mutagenic treatments. Mutants possessing a markedly darker spore colour than normal were also found. Certain variants categorised in Table 4 as showing rapid telial formation were also characterised by aberrant uredospore colour.

In all of the above, single or recurrent mutagenic treatments mutations for pathogenicity were observed. In the current context, usage of the terms "pathogenicity" and "virulence" follows that adopted by Watson (1970). Pathogenicity is a general term and is used in connection with such characters observed on the host as pustule size, volume of spores produced and the rate of growth of the pathogen. If a strain is virulent on a host, the gene or genes for resistance in the host are matched in the fungus by corresponding genes for virulence.

Pathogenic mutants exhibited either small uredopustule size or delayed pustule growth and development. Pathogenic mutants exhibiting subepidermal uredial formation were also found following recurrent mutagenic treatments. Certain aberrant colour mutants were characterised by one or more such pathogenic traits.

No mutants virulent on Saia were induced following initial EMS treatments. However, virulent mutants were induced in cultures BC1 and BC2 after one and two recurrent mutagenic treatments, respectively (Table 5).

TABLE 5
Effect of recurrent EMS treatments on mutation rates for virulence on Saia BC1 and BC2 of oat stem rust

Rust culture	Pertinent virulence gene*	Treatment	Recurrent cycle number	Total number pustules	Virulence mutants (v _{Sa})	
					Number	Rate (× 10 ⁻⁴)
BC1	V _{Sa}	15.7 × 10 ⁻² M, 2 hrs, 21 ± 1°C 2 hrs, 21 ± 1°C	Initial	20,000†	—	—
			1	25,600†	4	1.56
BC2	V _{Sa}	15.7 × 10 ⁻² M, 2 hrs, 21 ± 1°C 2 hrs, 21 ± 1°C 2 hrs, 21 ± 1°C	Initial	22,700†	—	—
			1	23,400†	—	—
			2	24,850†	2	0.80

V_{Sa} and v_{Sa} indicate avirulence and virulence on Saia, respectively.

* A single dominant gene was considered to govern resistance (see Discussion).

† Estimated by sampling procedure.

in cultures BC1 and BC2 of oat stem rust

Mutants	Rapid telial-forming variants with uredial colour					Total mutants			
	Normal no.	Yellow and orange no.	Grey-brown no.	Total no.	Mutation rate ($\times 10^{-4}$)	No.	Mutation rate and 95% limits ($\times 10^{-3}$)		
							O*	L	U
3.01	9			9	7.13	47	3.73	2.74	4.95
7.93	12	1		13	11.45	103	9.07	7.41	10.99
17.94	25			25	28.04	185	20.75	17.78	23.93
32.26	19	1	1	21	27.31	269	34.99	31.01	39.36
4.19	8			8	5.31	71	4.72	3.69	5.95
10.49	14			14	12.24	134	11.71	9.83	13.86
15.61	16	1		17	23.28	131	17.94	15.03	21.26
30.96	43	3		46	42.89	378	35.24	31.84	38.92
52.09	38	4		42	51.72	465	57.70	52.33	62.56

Subjecting an EMS-induced grey-brown colour mutant to mutagenic treatment yielded new variants. Of a total of approximately 20,000 pustules (estimated by sampling procedures) examined, eight white uredospore mutants were found.

The mutants, excepting those characterised by induced virulence on Saia, will be described in a subsequent paper.

Mutants Virulent on Cultivar Saia

The infection types produced by two virulent mutants of culture BC2 compared with the original culture are shown in Plate VII.

The four mutants virulent on Saia induced from culture BC1 exhibited identical infection types when tested on differential sets. The two mutants virulent on Saia induced from culture BC2 also produced identical infection types on differential sets. Characteristic infection types produced on differential sets by one representative mutant virulent on Saia induced from each of cultures BC1 and BC2 are shown in Table 6.

TABLE 6

Infection types exhibited on seedlings of various oat cultivars (resistance gene(s) in brackets) at $17 \pm 2^\circ\text{C}$ by mutants of oat stem rust with induced virulence

Cultivar	Mutant rust culture	
	BC1-a	BC2-a
(a) Canadian differentials		
Richland, 08 (A)	1-1	1-1+
Rodney, 0654 (B)	; 1	; 1-
White Tartar, 05 (D)	1+ 2=	3 3+
Jostrain, 0617 (E)	3c	3 3+
Eagle ² \times C.I.4023, 0658 (F)	2= 2-	1+ 2
C.I.5844-1, 0661 (H)	1+ 2 3c	3 3+
(b) Supplementary differentials		
Minnesota Ag. 331, 0615 (A D)	; 1+	1 1+
Saia, 0589 (Sa)	3c	3 3+
Strain designation	2-0-1*	7-H-1

* Indicates virulence on Saia.

Except for virulence on Saia, mutants produced no changes in infection types when tested on genotypes constituting the differential set. However, mutants of culture BC1 gave "3c" infection types on the universally susceptible cultivars Algerian, Bond, Fulghum, Victoria and Belar compared with "4" infection types produced on these cultivars by the original culture. Likewise, on these susceptible cultivars mutants of culture BC2 produced infection types ("3 3 +" with some chlorosis) similar to those exhibited on Saia. These were slightly but distinctly lower than the "4" infection types produced on these cultivars by the original cultures. Further, mutants showed 2-3 days' longer incubation and developmental periods and a general reduction in sporulation vigour compared with the respective original strains. These observations suggest that associated changes in pathogenicity were implicated in the production of these mutants.

DISCUSSION

Ethyl methanesulphonate proved highly mutagenic on *Puccinia graminis avenae*. Variability induced in the dikaryotic uredial stage involved traits differing as widely as uredospore colour, interval between uredial stage and subsequent telial development, virulence and pathogenicity.

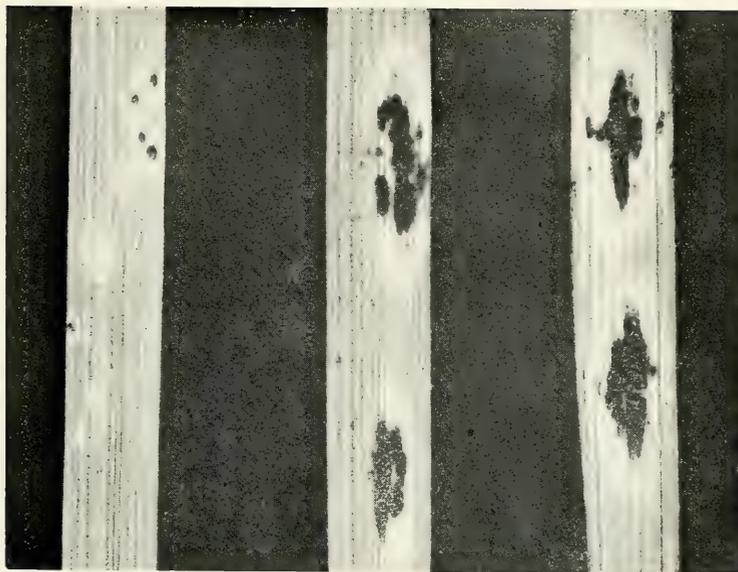
Genetic rather than temporary phenotypic changes were involved in the variability induced. Mutants remained stable over several generations of subculturing. Contingent upon proof from inheritance studies, the changes induced are believed to be due to recessive chromosomal gene mutations.

Mutants virulent on Saia differed from the original strains only by high infection types produced on this cultivar. The number of genes conditioning resistance in Saia is not definitely known. Murphy *et al.* (1958) concluded that the same two independent dominant genes in *Avena strigosa* accession C.D.3820 (which they considered agronomically identical with Saia) conditioned resistance to each of four races. On the other hand, Dyck (1966) found that the same single dominant gene in several accessions of *A. strigosa* governed resistance to each of a wide range of races. If Dyck's conclusions are accepted on the basis of the gene-for-gene hypothesis (Flor, 1956) mutations for virulence on Saia would involve a single locus and be recessive since avirulence is usually dominant.

Except for mutants virulent on Saia, no alterations in virulence were shown by the variants examined. Although certain aberrant colour mutants exhibited rapid telial formation or one or more pathogenic changes, absence of invariable association between the various traits indicated that independent mutations were involved. However, changes in incubation and developmental periods associated with a change in spore colour may have been due to pleiotropic gene effects.

The variants induced were, therefore, intrinsically similar to those reported to arise from spontaneous mutation or genetic recombination, although the rate of, and range in variability induced was greater than that ascribed to spontaneous mutation. This does not imply that such types would not occur naturally at a low frequency. However, most abnormal variants would obviously have low survival ability under natural conditions and would not be expected to persist.

Mutations for virulence were less readily induced than variation in other traits. Mutations for uredospore colour, particularly those affecting loss of spore wall pigment formation resulting in yellow or orange uredosori, occurred at the highest frequency. Increases in mutagen concentration, duration of treatment and temperature during treatment increased significantly mutation rate for colour mutants and rapid telial-forming variants. Recurrent mutagenic treatment also increased mutation frequency and, in addition, produced a wider spectrum of mutants.



a

b

c

Variation induced by EMS obviously has many applications, some of which are listed as follows :

1. Elucidation of the extent, causes, and nature of spontaneous variability.
2. As cultures for assessing the role of somatic hybridisation in creating variability in the oat stem rust fungus.
3. The rust reaction of segregating populations can be tested simultaneously with two or more rust strains differing in virulence and uredospore colour.
4. Difficulty is often experienced in producing teleutospores from field strains under glasshouse conditions. Teleutospores produced on mature plants in the field usually originate from uredospores of unknown genotypes. Rapid telial-forming variants induced from identified field strains are obviously useful for determination of their genotypes and for studies on the inheritance of virulence and other traits by infection of the barberry. Inheritance studies can be greatly expedited since rapid telial-forming variants provide abundant teleutospores after an extremely short transitory uredial stage.
5. Analysis of uredospore pigments in differently coloured mutants may be useful in elucidating the biosynthetic pathway of carotenogenesis in rust fungi and in fungi in general.

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EXPLANATION OF PLATE VII

Infection types exhibited on Saia by original and two virulent mutants of strain 7–H of oat stem rust ($\times 3.5$). a. Original strain 7–H : “; 1–” infection types. b–c. Mutant strains : “3 3+” infection types.

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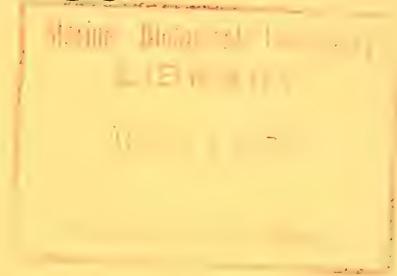
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A NEW SPECIES OF *PHYTOSEIUS* RIBAGA
(ACARINA : PHYTOSEIIDAE) FROM APPLE IN AUSTRALIA

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[Accepted for publication 19th June 1974]

Synopsis

Phytoseius fotheringhamiae n. sp. (Acarina : Phytoseiidae) is described from apple in New South Wales, Australia. It is closely related to *Phytoseius woodburyi* DeLeon.

INTRODUCTION

The species of phytoseiid mite described in this paper was collected from apple trees at Bathurst, New South Wales. It was found mainly on the undersides of leaves in orchards of young unbearing apple trees, in commercial orchards of Granny Smith apple trees and on single neglected apple trees ("backyard trees") during the years 1971 to 1973.

Genus *PHYTOSEIUS* Ribaga

Phytoseius Ribaga, 1904, *Riv. Patol. Veg.*, 10 : 177

Phytoseius (Phytoseius) fotheringhamiae, n.sp.

(Figs 1-8)

Diagnosis. *Phytoseius fotheringhamiae* n. sp. is closely related to *Phytoseius woodburyi* DeLeon from which it is distinguished by the following characteristics. The lateral and the anterior sublateral setae are longer in the new species than in *P. woodburyi*. The clunals are serrate in the new species but smooth in *P. woodburyi*. A pair of large pores caudomedial to M_1 in the new species is missing in *P. woodburyi*. The cervix of the spermatheca in the new species is much longer than in *P. woodburyi*.

Measurements listed are the mean and standard deviation of 20 specimens in microns, if not otherwise indicated.

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FEMALE

Dorsum : (Fig. 1) The dorsal shield, length 293 ± 6 , width at L_4 132 ± 3 , is rugose and bears 15 pairs of setae (inclusive S_1), eight lateral, one median, three dorsal, one pair each of clunals and verticals, and one pair of anterior sublateral setae S_1 (on the dorsal shield). The setae measure in length : verticals 35 ± 2 ; D_1, D_2, D_3 and $M_1 = 4.5 \pm 0.5$; clunals 8 ± 1 ; $L_1 = 52 \pm 4$; $L_2 = 16 \pm 2$; $L_3 = 30 \pm 2$; $L_4 = 12 \pm 2$; $L_5 = 115 \pm 7$; $L_6 = 83 \pm 4$; $L_7 = 82 \pm 5$; $L_8 = 86 \pm 4$; anterior sublaterals (S_1) 50 ± 2 . Setae $L_1, L_5, L_6, L_7, L_8, S_1$ and the verticals

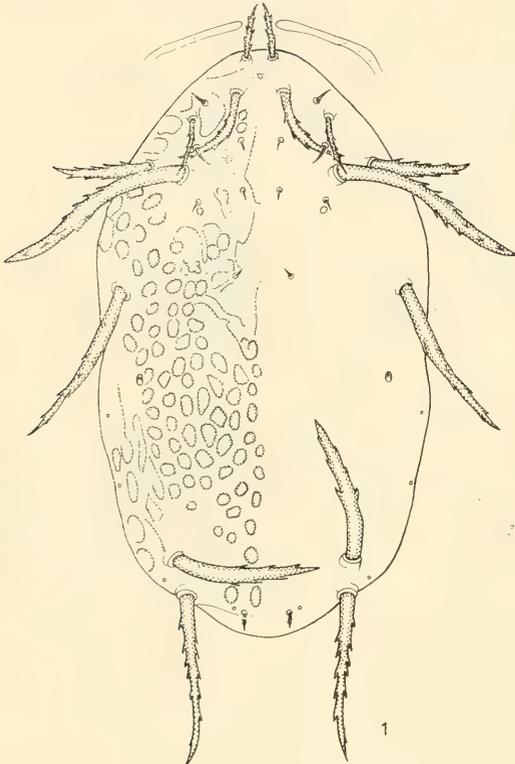


Fig. 1. Dorsal shield of female.

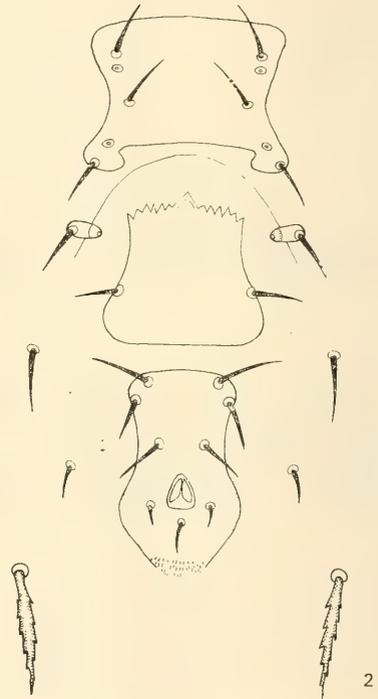


Fig. 2. Venter of female.

are serrate, L_3 and the clunals are slightly serrate. All other setae are smooth. Setae S_1, L_1, L_5, L_6, L_7 and L_8 are unusually thick. There is one pair of large pores posterolaterally, one pair of large pores caudomedial to the first median setae (M_1), and one pore between the vertical and L_1 . Peritremes extend to the vertical setae.

Venter : (Fig. 2) (Measurements of holotype only) Sternal shield, length 63, width 91, smooth with three pairs of setae. Setae IV are on oval shaped metasternal shields. Genital shield, length 94, width 101, normal with a pair of genital setae. Ventrianal shield, length 119, width 64, elongate vase shaped with three pairs of preanal setae.

Chelicerae : (Fig. 3) The fixed finger measures 36 ± 1 (ten measurements) in length and is provided with three teeth and a pilus dentilis. The movable finger, length 40 ± 1 , has a single tooth.

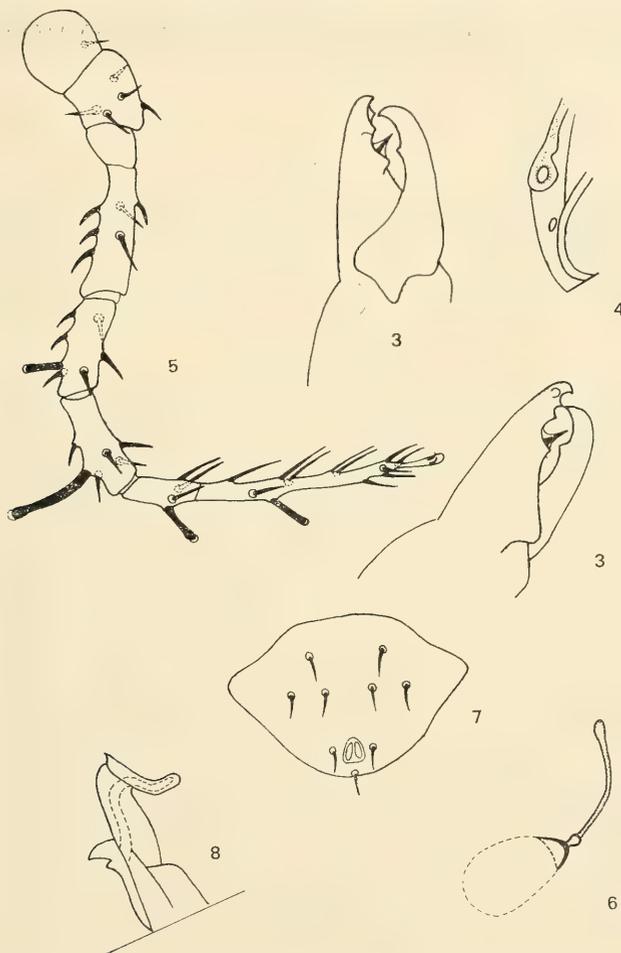
Peritrematal shield : (Fig. 4).

Length of macrosetae on leg IV as follows: (Fig. 5) Sge IV 17 ± 2 ; Sti IV 49 ± 3 ; St IV₁ 25 ± 3 ; St IV₂ 20 ± 2 ; Genu II $2, \frac{2 \cdot 2}{0}, 1$; Genu III $1, \frac{2 \cdot 2}{0}, 1$.

Spermatheca: (Fig. 6) (Two measurements) With cup or bowl shaped cervix. The major duct is 35–40 long. The atrium is 5 broad and 4–5 long. The cervix has a diameter of 12–14 where it joins the vesicle.

MALE

Dorsum: (Measurements of three specimens) Length 260–274, width 120–130, smaller than female; the chaetotaxy and the shape of the setae resemble those of the female. The setae are, however, relatively shorter. Verticals =



Figs 3–8. 3. Chelicerae of female. 4. Peritrematal shield of female. 5. Leg IV of female. 6. Spermatheca of female. 7. Ventrianal shield of male. 8. Spermatodactyl of male.

29–33, D₁, D₂ and D₃ all approximately 4; M₁ = 5–6, clunals = 6–7, L₁ = 38–46, L₂ = 12–17, L₃ = 25–29, L₄ = 12–13, L₅ = 70–80, L₆ = 48–62, L₇ = 51–55, L₈ = 43–49, anterior sublaterals (S₁) = 35–43.

Venter: Ventrianal shield (Fig. 7) smooth with three pairs of preanal setae.

Spermatodactyl: (Fig. 8) Spermatodactyl has a terminal heel and its lateral process is distinct (no crest present on shank).

Type. Female holotype from Bathurst, N.S.W., Australia, January, 1971, E. Schicha, on leaves of sprayed Granny Smith apple trees. Deposited in South Australian Museum, Adelaide, S.A., Australia.

Paratypes. Eight females and four males taken with the holotype from the same locality. Deposited as follows: four females and two males at Biological and Chemical Research Institute, Rydalmere, N.S.W., Australia; two females and one male at Division of Plant Industry, Florida Department of Agriculture and Consumer Services, Gainesville, Florida, U.S.A.; two females and one male at South Australian Museum, Adelaide.

Reference

DELEON, D., 1965.—Phytoseiid mites from Puerto Rico with descriptions of new species (Acarina : Mesostigmata). *Fla Ent.*, 48 : 121-131.

SILURIAN RUGOSE CORALS FROM THE MUMBIL AREA, CENTRAL NEW SOUTH WALES

R. A. McLEAN*

(Plates VIII–XII)

[Accepted for publication 19th June 1974]

Synopsis

Six species of rugose corals (three new) are described from strata of probable late Wenlock to early Ludlow age in the Mumbil area, near Wellington in central New South Wales. They comprise representatives of the genera *Holmophyllum* Wedekind, *Holmophyllia* Sytova, *Coronoruga* Strusz, *Pilophyllum* Wedekind and *Palaeophyllum* Billings. Several of the forms described from this area by Strusz (1961) are revised. The holotype of "*Baeophyllum*" *colligatum* Hill, 1940 is refigured and its affinities discussed.

INTRODUCTION

The first detailed study of the Palaeozoic strata of the Mumbil-Neurea-Dripstone area, some 24 km south-east of Wellington, was that of Strusz (1960). He defined a sequence consisting in the lower part of the Oakdale Formation of Upper Ordovician age, overlain by the Mumbil Formation, regarded as being Upper Llandovery to Ludlow in age. The Mumbil Formation was subdivided into a lower, Narragal Limestone Member, and upper, Barnby Hills Shales Member. Aspects of the coral fauna of this sequence were examined by Strusz (1961). Subsequent study of this region by Vandyke (1970, unpubl.), particularly in the region of the Oakdale Anticline (Text-fig. 1), has led to considerable reappraisal of the stratigraphic sequence and the age of the constituent formations (Vandyke and Byrnes, 1974). The Oakdale Formation is now elevated to group status and comprises a lower, Cypress Hill Volcanics and an upper, Mona Vale Siltstone (Vandyke and Byrnes, 1974). Unconformably overlying this is the Dripstone Group, consisting of the Wylinga Formation, Warderie Volcanics and Catombal Park Formation, in ascending stratigraphic order. The Dripstone Group is equivalent to the upper part of the former Oakdale Formation of Strusz (1960). Finally, the Mumbil Formation was also raised to group status and includes the Narragal Limestone and overlying Barnby Hills Shale.

The rugose corals described herein are represented in three horizons of the Dripstone and Mumbil Groups. From the Catombal Park Formation of the Oakdale Anticline *Palaeophyllum oakdalensis* sp. nov., *Holmophyllum struzi* sp. nov. and *Holmophyllia maculosa* sp. nov. are described. *P. oakdalensis* is particularly abundant in the calcareous beds at the base of this formation while the other two species are rare. The Narragal Limestone was divided in some places into an upper and lower member separated by a thin horizon of volcanic sandstone (Vandyke, 1970; Vandyke and Byrnes, 1974). From the upper

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member of this formation *Holmophyllia* cf. *simplex* (Lewis) is described, and *Coronoruga dripstonense* Strusz probably also comes from this upper member. *Pilophyllum multiseptatum* (Strusz) occurs in a limestone lens of the Barnby Hills Shale south of the Bell River (probably the lens marked as Loc. 7 in Text-fig. 1). This lens was regarded as equivalent to the Narragal Limestone by Strusz (1961) but was considered to overlie that formation by Vandyke (1970).

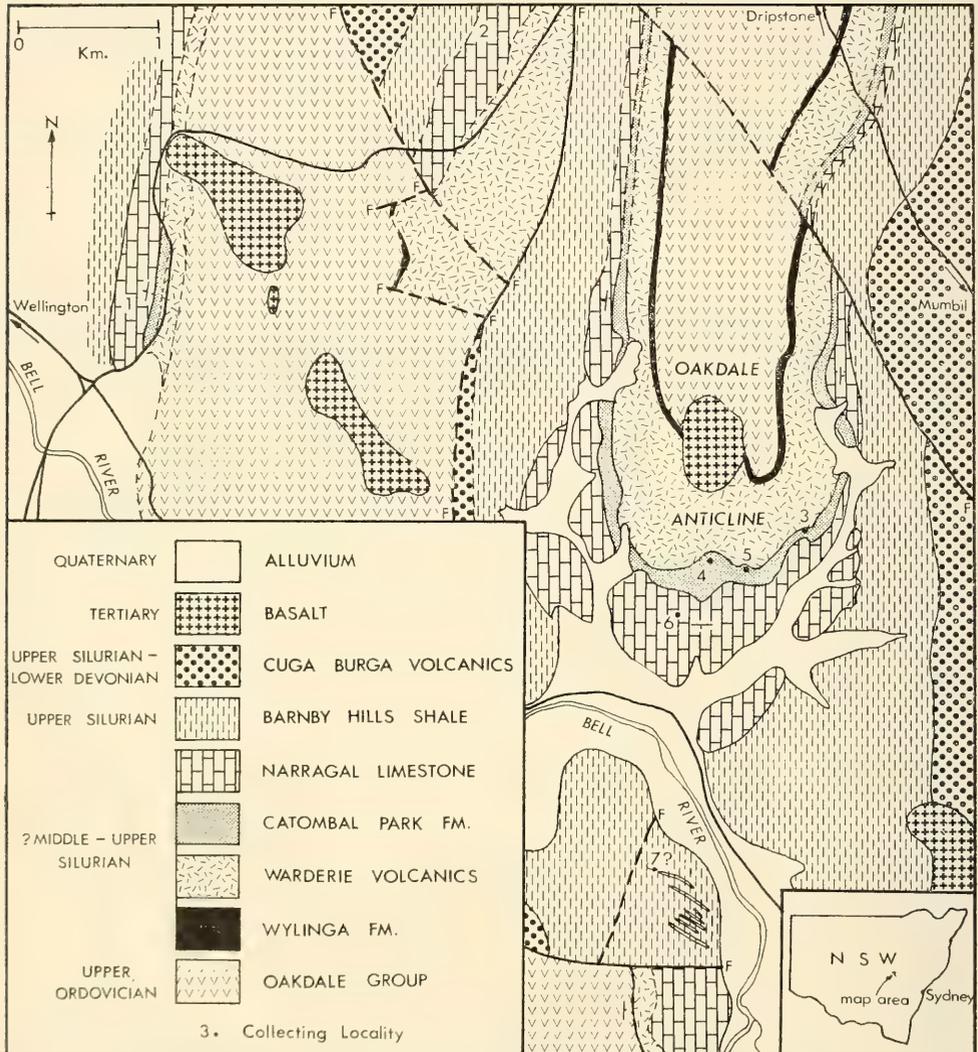


Fig. 1. Geological sketch map of the Mumbil area, showing collecting localities. Geology based on Vandyke (1970, unpubl.).

An unconformity between the Oakdale Group and Wylinga Formation was recognised by Vandyke (1970). In the Oakdale Anticline, shales with *Retiograptus* occur below the unconformity and, to the west, definite Ordovician graptolites and trilobites are found in shales of the Oakdale Group (Strusz, 1960, 1961; Vandyke, 1970; Webby, 1973). In the limestone lenses of the Wylinga Formation in the Oakdale Anticline, the rugosan *Rhizophyllum* is represented,

comprising forms showing similarities to those of the ?late Wenlock to Ludlow of the Yass District (see also Vandyke, 1970). This would suggest that the Llandovery and probably much of the Wenlock is missing in the sequence. The species of *Rhizophyllum* show no close similarities to the large form represented in the Upper Llandovery (Rosyth and Quarry Creek Limestones) of central New South Wales (McLean, 1974b).

From horizons low in the Barnby Hills Shale overlying the Narragal Limestone, abundant *Pristiograptus bohemicus* (Barrande) is represented (Strusz, 1960), together with rare *Neodiversograptus nilssoni* (Lapworth) (Vandyke, 1970; C. J. Jenkins, pers. comm., 1974). Hence the Narragal Limestone would not appear to range in age higher than the *nilssoni* zone (basal Ludlow). Therefore the Dripstone and Mumbil Groups as defined by Vandyke and Byrnes (1974) and the faunas described in this paper would appear to range most probably from late Wenlock to early Ludlow in age.

Specimen numbers in the University of Sydney Palaeontological Collections bear the prefix SUP and where more than one section has been prepared from the one specimen, they have the suffix a, b, etc. Numbers of specimens in the palaeontological collections of the Australian Museum, Sydney, have the prefix AM.F and thin sections in these collections bear the prefix AM.

SYSTEMATIC PALAEOLOGY

Family CYSTIPHYLLIDAE Edwards and Haime, 1850

Genus HOLMOPHYLLUM Wedekind, 1927

- 1927 *Holmophyllum* Wedekind, p. 31
 1940 *Nipponophyllum* Sugiyama, p. 115
 1940 *Baeophyllum* Hill, p. 403
 1961 *Nipponophyllum* (*part.*); Strusz, p. 346
 1963 *Nipponophyllum* (*part.*); Ivanovski, p. 112
non 1934 *Holmophyllum*; Lewis, p. 95

For further synonymy see McLean, 1974b.

Type species. *H. holmi* Wedekind, 1927. Eke Beds (Ludlow), Gotland.

Diagnosis. Solitary or fasciculate corallum. Septa consist of discrete rhabdacanthine trabeculae piercing several dissepiments or tabulae. Tabularium generally clearly differentiated from peripheral zone of axially inclined dissepiments.

Discussion. The affinities and species composition of the genus *Holmophyllum* were reviewed by McLean (1974b). It was suggested in that paper that the branching form *Nipponophyllum* Sugiyama, 1940, was closely allied to *Holmophyllum*, but was tentatively separated from that genus on the basis of having more contiguous septal spines, particularly in the Tadzhikistan representatives of the genus. There is insufficient figured material of the type species of *Nipponophyllum*, *N. giganteum* Sugiyama, 1940, for detailed comparison but from what is available the septal spines would appear to be mainly discrete (Sugiyama, 1940, Pl. XXX, figs 3, 4; Text-fig. 3). The Australian genus *Baeophyllum* Hill, 1940 (regarded as a synonym of *Nipponophyllum* by most subsequent workers, e.g. Hill, 1956; Strusz, 1961; Ivanovski, 1963; Lavrusevich, 1967) was described as having both complete septa and discrete septal spines (Hill, 1940, p. 404). However, re-examination of the type material of *B. colligatum* Hill has shown no definite evidence of complete septa, although material is extensively recrystallised. Discrete septal spines may be sparsely seen and the holotype of the species (AM.F 9148) is re-illustrated herein for

comparison with other forms (Text-fig. 2; Pl. VIII, figs 1-5). Lavrusevich (1967) regarded *Nipponophyllum* as a branching form of *Holmophyllum* but it is felt that such a difference is probably not of generic importance. Hence both *Nipponophyllum* and *Baeophyllum* are here regarded as synonyms of *Holmophyllum*.

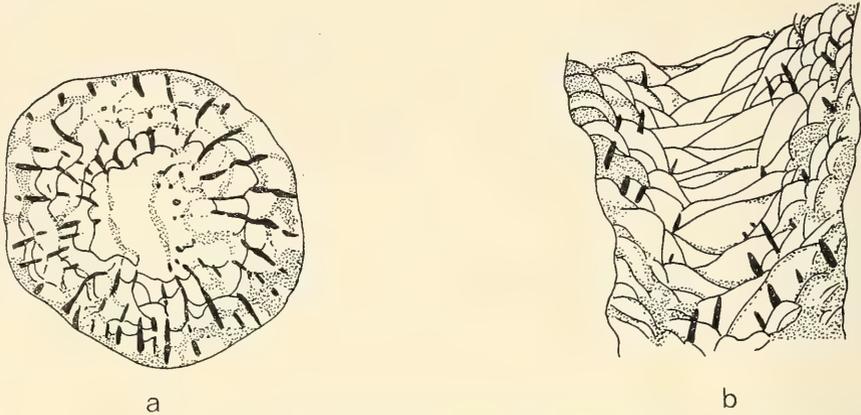


Fig. 2. *Holmophyllum colligatum* (Hill), Bowspring Limestone, Yass. a. AM704, holotype, transverse section, $\times 6$. b. AM 704, holotype, longitudinal section, $\times 6$.

The Tadzhikistan species of "*Nipponophyllum*" described by Lavrusevich (1967) are referred to *Holmophyllia* Sytova, 1970 (see below).

Species of *Holmophyllum* bearing a branching corallum (Group III of McLean, 1974b) are now taken to include *H. obscurum* Smelovskaya, *H. subtenuis* Shurygina, ?*H. primaevum* Wang, *H. giganteum* (Sugiyama), *H. colligatum* (Hill) and *H. struszi* sp. nov.

Holmophyllum struszi sp. nov.

Pl. VIII, figs 6-9, Pl. IX, figs 1-3; Text-fig. 3

1961 *Nipponophyllum* sp. cf. *giganteum* Sugiyama, 1940; Strusz, p. 347, Pl. 43, figs 3, 4; Pl. 45, fig. 12.

Derivation of name. After Dr. D. L. Strusz, who first worked on the coral faunas of the Mumbil area.

Material. Holotype SUP 74220, Paratypes SUP 10289, 40279 Catombal Park Formation, Oakdale Anticline, Mumbil area (Loc. 4). ?Late Wenlock.

Diagnosis. Corallum fasciculate or phaceloid. Septal spines stout, sparsely developed, of moderate length. Dissepiments large, strongly elongate; tabulae complete and incomplete, widely spaced, in strongly sagging series.

Description. Corallum fasciculate or phaceloid, showing outgrowths of the dissepimentarium for support of adjacent corallites. Dimensions of corallum reach at least 27 cm high, with diameter of 25 cm. Increase is apparently calicinal. Corallites are closely spaced with diameter ranging from 9-12 mm in mature specimens.

Septal spines are rather stout, in 30-36 radial rows which are usually clearly defined. Spines are confined mainly to surface of dissepiments and are only rarely developed on tabulae. They generally pierce no more than 2-3 dissepiments.

ments. Trabecular microstructure is obscured by recrystallisation (Pl. VIII, fig. 7).

Dissepiments are mainly strongly elongate, of very variable size although generally large, particularly at corallite periphery. They occur in 2-5 rows and are very steeply inclined towards axis of corallite. Tabulae are both complete and incomplete, very widely spaced and form strongly sagging series. Tabularium occupies approximately half of corallite diameter.

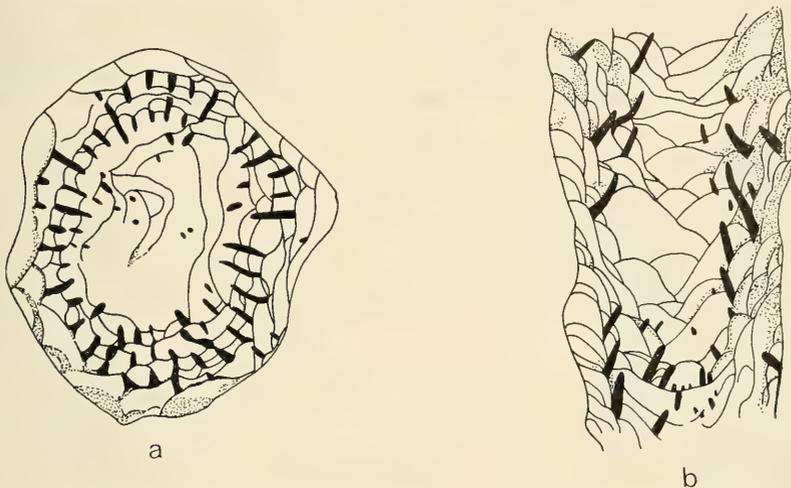


Fig. 3. *Holmophyllum struszi* sp. nov., Catombal Park Formation, Mumbil area. a. SUP 74220e, holotype, transverse section, $\times 4$. b. SUP 74220h, holotype, longitudinal section, $\times 4$.

Remarks. Strusz (1961) closely compared this form with *H. giganteum* (Sugiyama, 1940) from the Lower Ludlow of the Kitakami Mountains, Japan, the latter being type species of "*Nipponophyllum*". However, *H. giganteum* may be clearly distinguished by its larger number of septal spines and flatter, closer, more complete tabulae. It is felt therefore that the New South Wales form warrants erection of a new species.

H. colligatum (Hill, 1940) from the Bowspring Limestone (early or middle Ludlow) of Yass, New South Wales, is closely comparable to *H. struszi* in growth form but differs in having generally sparser, more irregularly developed septal spines, together with flatter more complete tabulae.

Genus HOLMOPHYLLIA Sytova, 1970

- 1934 *Holmophyllum*; Lewis, p. 95 (*non* Wedekind, 1927)
- ? 1952 *Holmophyllum* (*part.*); Bulvanker, p. 12
- 1967 *Nipponophyllum*; Lavrusevich, p. 18 (*non* Sugiyama, 1940)
- ? 1968 *Gukoviphyllum* Sytova, p. 54
- 1970 *Holmophyllia* Sytova, p. 68
- ? 1973 *Gukoviphyllum*; Fedorowski and Gorianov, p. 32

Type species. *Holmophyllia boreale* Sytova, 1970. Vaygach Horizon (Lower Devonian), Vaygach Island.

Diagnosis. Solitary or fasciculate corallum. Septa comprise rhabdacanthine trabeculae partly fused vertically near corallite periphery,

becoming discrete at their axial ends and in tabularium. Tabulae complete and incomplete, dissepiments very variable in shape and abundance.

Discussion. *Holmophyllia* is distinguished from *Holmophyllum* Wedekind on the basis of having its rhabdacanthine trabeculae partly fused vertically to give the impression of complete septa in the peripheral region of the corallite. This small difference could perhaps be regarded as of subgeneric importance only but it does appear to be a basic difference and so for the present full generic status for *Holmophyllia* is retained.

The similarities between *Gukoviphyllum* Sytova, 1968, and *Holmophyllum* and "*Nipponophyllum*" were discussed by McLean (1974b). In its long, partly fused septal spines *Gukoviphyllum* is also closely allied to *Holmophyllia*. However, according to Sytova (1968, p. 54; 1970, p. 68) the former lacks rhabdacanths, the trabeculae instead having a fan-shaped appearance, although this may be a feature of preservation. In all other respects, especially the fused spines, *Gukoviphyllum* appears identical to *Holmophyllia* (see *G. septatum*, Bulvanker, 1952, Pl. IV, figs 2-4; Sytova, 1968, Pl. I, fig. 5b; Fedorowski and Gorianov, 1973, Pl. VI, fig. 7b) and most probably *Holmophyllia* will prove to be a junior synonym of *Gukoviphyllum*. However, until the septal microstructure of *Gukoviphyllum* is illustrated and its synonymy with *Holmophyllia* confirmed or denied, it is felt that the latter genus should be retained for forms bearing definite rhabdacanths.

Holmophyllum simplex Lewis, 1934, from ? Wenlock pebbles in the Stack Series of the Isle of Man, has rather short rhabdacanthine trabeculae but these are clearly fused peripherally (Lewis, 1934, Pl. VIII, fig. a). The species is here regarded as a representative of *Holmophyllia*. Sytova (1970, p. 67) included it in *Gukoviphyllum*, but its definite rhabdacanths (Wang, 1947) would seem to preclude it from that genus.

The three species of "*Nipponophyllum*" (*N. turkestanicum*, *N. minimum* and *N. reimani*) described by Lavrusevich (1967) from the Upper Silurian of Tadzhikistan all exhibit partly fused, long rhabdacanthine trabeculae and hence are included here in *Holmophyllia*.

The following species are here regarded as representative of *Holmophyllia*: *H. boreale* Sytova (type species), *H. simplex* (Lewis), *H. turkestanicum* (Lavrusevich), *H. minimum* (Lavrusevich), *H. reimani* (Lavrusevich) and *H. maculosa* sp. nov.

Range. ? Wenlock of Isle of Man; ? Late Wenlock of New South Wales; Upper Silurian of Tadzhikistan; Lower Devonian of Vaygach Island. "*Gukoviphyllum*" is represented in the Pridoli of Podolia and late Ludlow-early Pridoli of Estonia.

Holmophyllia maculosa sp. nov.

Pl. IX, figs 4-7; Text-fig. 4

Derivation of name. Latin, *maculosus* = spotted, referring to appearance of tabularium due to septal spines in transverse section.

Material. Holotype SUP 40261. Catombal Park Formation, Oakdale Anticline, Mumbil area (Loc. 5). ? Late Wenlock. Collected by A. Byrnes, 1970.

Diagnosis. Corallum fasciculate. Septal spines partly fused vertically in peripheral regions of corallite, becoming discrete axially. Entirely discrete septal spines abundantly developed in tabularium. Dissepiments in narrow zone, elongate; tabulae closely spaced, forming strongly sagging series.

Description. Only one small fragment of a corallum was available for study. Growth form is fasciculate, the corallites quite widely spaced (average 5 mm). Corallite diameter ranges from 9-13 mm in mature stage.

Septa comprise long rhabdacanth, partly fused vertically in peripheral regions of corallite, becoming discrete at their axial ends. In inner parts of dissepimentarium, septal spines are entirely discrete, composed of broad rhabdacanth. In tabularium, spines are thinner and abundantly developed on tabularial crests. Spines pierce up to 8 dissepiments or tabulae. In transverse section well-defined radial rows of spines are evident with differentiation into major and minor septa. Minor septa consist mainly of one spine in a transverse section, extending 0·2–0·3 of length of major septa which are composed of several spines. Major septa, which range in number from 31–35, cannot usually be clearly traced far into tabularium, where they are replaced by an irregular cluster of spines (Text-fig. 4a; Pl. IX, fig. 7). Minor septa are not always clearly apparent owing to extensive recrystallisation around most corallite margins.

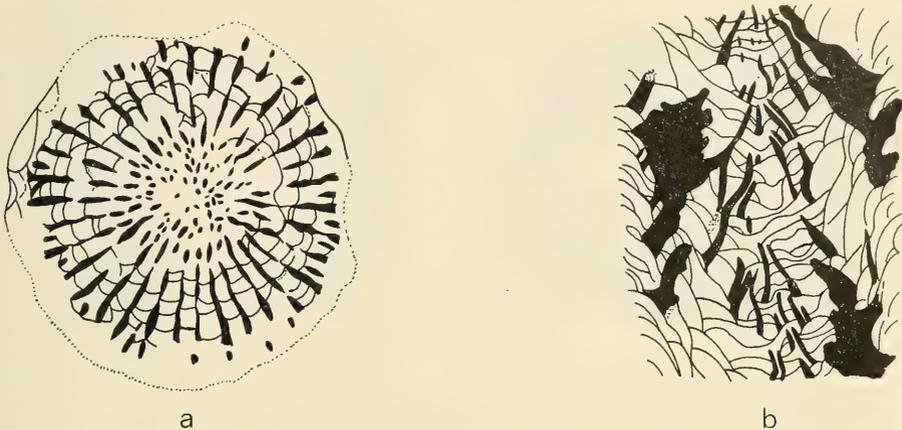


Fig. 4. *Holmophyllia maculosa* sp. nov., Catombal Park Formation, Mumbil area. a. SUP 40261a, holotype, transverse section, $\times 5$. b. SUP 40261c, holotype, longitudinal section, $\times 5$.

Dissepiments are weakly to strongly elongate, of moderate size and very steeply inclined to corallite axis. They occur generally in 2–3 rows. Tabulae are both complete and incomplete, occurring in strongly sagging series. Peripherally tabulae are widely spaced and steeply inclined to axis, becoming flat or weakly arched in axial region where they are very closely spaced.

Remarks. In its strong development of discrete septal spines in the tabularium and long major septa this species is comparable to the branching form *H. reimani* (Lavrushevich, 1967) from the Upper Silurian of the Turkestan Range of Tadzhikistan. However, the latter species may be distinguished by having fewer septa, longer minor septa and a very narrow tabularium.

Holmophyllia cf. *simplex* (Lewis, 1934)

Pl. IX, fig. 8; Pl. X, figs 1–7; Text-fig. 5

Material. SUP 39184, representing several corallites embedded in a stromatoporoid. Upper member of Narragal Limestone, Oakdale Anticline, Mumbil area (Loc. 6). Collected by A. Byrnes, 1970. SUP 74228, same horizon, western area of outcrop (Loc. 1). Late Wenlock or early Ludlow.

Diagnosis. Corallum solitary. Septal spines of short to moderate length, in partial lateral and vertical contact peripherally, forming distinct major and minor septa in late growth stages. Septal spines mainly discrete where based on dissepiments, but not developed in tabularium. Dissepiments small; tabulae widely spaced, strongly sagging.

Description. Corallum appears to be solitary, growing commensally with a stromatoporoid. Corallites are subcylindrical with height at least 30 mm and diameter reaching 9 mm.

Septal spines are of short to moderate length, rhabdacanthine, dilated at corallite wall to be in lateral contact, forming a very narrow septal stereozone in some places. Spines are also partly fused vertically at corallite periphery (Pl. X, figs 2, 4) but where spines are based on dissepiments, which is uncommon, they are typically discrete.

It is rare for spines to extend through dissepimentarium to tabularium. Septa range in number from 46–50 in mature corallites, minor septa being 0·2–0·5 of length of major septa, the latter extending up to 0·6 of corallite radius. Minor septa do not appear to be developed until late in ontogeny.

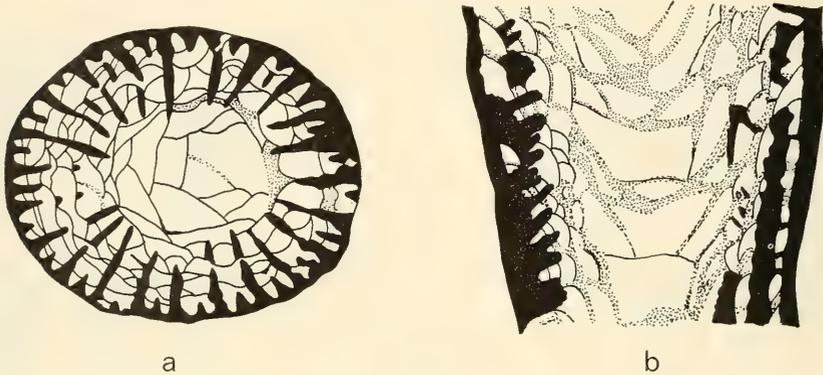


Fig. 5. *Holmophyllia* cf. *simplex* (Lewis), Narragal Limestone, Mumbil area. a. SUP 39184a, transverse section, $\times 7$. b. SUP 39184c, longitudinal section, $\times 5$.

Dissepiments are small, globose to weakly elongate, in 3–4 rows steeply inclined to corallite axis. Tabulae form very strongly sagging series, complete and incomplete, widely spaced.

Remarks. This form appears very closely similar to the ? Wenlock species *H. simplex* (Lewis, 1934) from the Stack Series, Isle of Man. The only difference would seem to be greater development of small, globose dissepiments at earlier growth stages in the New South Wales material. However, as only one figured longitudinal section of the type material is available (Lewis, 1934, Pl. VIII, fig. a), the New South Wales form cannot be more closely compared.

Genus CORONORUGA Strusz, 1961

1961 *Coronoruga* Strusz, p. 347

Type species. *C. dripstonense* Strusz, 1961. Narragal Limestone, Mumbil area. Late Wenlock or early Ludlow.

Diagnosis. (Based on Strusz, 1961, p. 347.) Large solitary corallites with a wide dissepimentarium separated from a rather narrow tabularium by a narrow stereozone in which are embedded short, discrete trabeculae.

Discussion. Ivanovskiy (1965a, b) suggested *Coronoruga* may be a synonym of *Gyalophyllum* Wedekind, 1927. However, the latter has coarse, very closely spaced septal spines almost completely occupying the space of the dissepimentarium whereas in *Coronoruga* the spines are largely confined to the stereozone separating the dissepimentarium and tabularium. The septal structure of *Coronoruga* with trabeculae, wrapped in lamellar sclerenchyme, occurring in layers on dissepiments and tabulae is comparable to that of *Angullophyllum*

McLean, 1974*b*, found in the Upper Llandoverly of Angullong, central New South Wales. The latter differs in its smaller skeletal elements and compound growth form. *Coronoruga* appears to be endemic to Australia.

Coronoruga dripstonense Strusz, 1961

Pl. X, figs 8–10, Pl. XI, figs 1–3

1961 *Coronoruga dripstonense* Strusz, p. 348, Pl. 42, figs 9, 17

Material. Holotype SUP 11104, Paratypes SUP 11101, 11212–11215, 11195, 11198. Narragal Limestone, Mumbil area (Loc. 2). Late Wenlock or early Ludlow.

Diagnosis. See Strusz, 1961.

Description. See Strusz, 1961.

Remarks. From further sections made of the paratypes it is evident that where layers of sclerenchyme occur on dissepiments and tabulae, short septal spines are sparsely present although recrystallisation generally obscures this feature. The trabecular microstructure is largely also obscured by recrystallisation but it appears most probably to be rhabdacanthine, the individual trabeculae being wrapped in lamellar sclerenchyme.

Family ENDOPHYLLIDAE Torley, 1933

Genus PILOPHYLLUM Wedekind, 1927

- 1927 *Pilophyllum* Wedekind, p. 39
 ? 1937 *Sinospongophyllum* Yoh, p. 56
 ? 1942 *Sinospongophyllum*; Hill, p. 20
 1944 *Pilophyllum*; Wang, p. 23
 1952 *Pilophyllum*; Bulvanker, p. 20
 1956 ? *Pilophyllum*; Hill, p. F301
 1961 *Nipponophyllum* (*part.*); Strusz, p. 346 (*non* Sugiyama, 1940)
 1966 *Pilophyllum* (? *part.*); Sytova and Ulitina, p. 227
 1968 *Pilophyllum* (*part.*); Lavrusevich, p. 110
non 1958 *Pilophyllum*; Kaljo, p. 115
non 1960 *Pilophyllum*; Zheltonogova, p. 77
non 1963 *Pilophyllum*; Ivanovskiy, p. 60
non 1969 *Pilophyllum*; Hill *et al.*, p. 5, 12.

Type species. *P. keyserlingi* Wedekind, 1927. Hemse Beds (Ludlow), Gotland.

Diagnosis. Solitary or fasciculate corallum. Septa thin, with well-defined stereozone on corallite wall and dissepimental surfaces. Dissepiments typically large, lonsdaleoid, sparsely developed. Tabulae incomplete, in arched series.

Discussion. The genus *Sinospongophyllum* Yoh, 1937, may well be synonymous with *Pilophyllum*. Hill (1942) considered the type species, *S. planotabulatum* Yoh, 1937 (Givetian, Kwangsi) differed from *Pilophyllum* in lacking greatly thickened septa and having more complete tabulae. However, from the illustrations of Wedekind (1927, Pl. 8, figs 1–6), the extent to which the septa of *Pilophyllum* are thickened in the stereozone is quite variable, that of *P. progressum* Wedekind being quite comparable to that of *S. planotabulatum* (Wedekind, 1927, Pl. 8, figs 5, 6; Yoh, 1937, Pl. VI, figs 2–5). The tabulae of *Sinospongophyllum* are certainly more complete than is evident in the Gotland specimens of *Pilophyllum* illustrated by Wedekind (1927) but this is probably not a significant generic difference. The material described below as *P. multiseptatum* (Strusz) has tabulae roughly intermediate in character between *P. keyserlingi* Wedekind (type species) and *S. planotabulatum*. Consequently *Sinospongophyllum* is herein tentatively regarded as a synonym of *Pilophyllum*. "*Sinospongo-*

phyllum” is also represented in the Lower Devonian of Queensland (“*S.*” *abrogatum* Hill, 1942, p. 20). Affinities of “*Sinospongophyllum*” with other Devonian forms have been reviewed by Hill and Jell (1970, p. 64).

Of Silurian genera, *Pilophyllum* shows perhaps closest similarities to *Kyphophyllum* Wedekind, 1927 (probably a synonym of *Strombodes* Schweigger, 1819—see McLean, 1974a). As pointed out by Merriam (1972, p. 37), *Pilophyllum* differs from “*Kyphophyllum*” in having a broader septal stereozone and sparser development of dissepiments, the latter tending to be larger than those of “*Kyphophyllum*”. The type species of *Strombodes*, *S. stellaris* (Linnaeus) with its narrower dissepimentarium shows close similarities to *Pilophyllum* in longitudinal section (Smith, 1945, Pl. 29, fig. 2), but its lack of stereozone serves to distinguish it from *Pilophyllum*.

The genus *Pseudopilophyllum* was proposed by Lavrusevich (1971) for forms similar to *Pilophyllum* but differing in having numerous small dissepiments as opposed to the large, sparse dissepiments of *Pilophyllum*. It may be distinguished from *Pilophyllum* also by possessing thickened septa in the tabularium. “*Pilophyllum*” *moyeroense* Ivanovskiy, 1963, from the Upper Wenlock of the Siberian Platform was designated as type species of *Pseudopilophyllum* and the species is also represented in the Lower Wenlock (Horizon K) of Tadzhikistan (Lavrusevich, 1971, p. 69).

The three species of *Pilophyllum* described by Kaljo (1958) from the late Ordovician-early Silurian of Estonia (*P. porosum*, *P. zonatum* and *P. massivum*) all possess an axial structure and thus would not appear to be representative of that genus. This has been recognised also by Sytova and Ulitina (1966, p. 227) and Lavrusevich (1968, p. 110). Ivanovskiy (1965*b*) has listed these three species as possible representatives of *Paliphyllum* Soshkina.

Zheltonogova (1960) described two species of *Pilophyllum* (*P. insolitum* and *P. angustum*) from the Tom-Chumysh Beds (Lower Devonian) of the Salair, south-west Siberia. Both these forms require further study but do not appear to be representative of *Pilophyllum* as suggested by Sytova and Ulitina (1966, p. 228) and Hill (1967, p. 668). “*P.*” *insolitum* possesses numerous dissepiments and “*P.*” *angustum*, while appearing rather similar to *Pilophyllum* in longitudinal section (Zheltonogova, 1960, Pl. 8–18, fig. 1), does not appear to have clearly developed lonsdaleoid septa and has been referred to the new genus *Salairophyllum* by Besprozvannykh (1968).

P. bimumurum Sytova in Sytova and Ulitina, 1966, from the Lower Devonian Nadaŭnasuy Horizon of Kazakhstan differs from typical *Pilophyllum* in having an “inner wall” of thickened septa. However, in all other respects it appears closely similar to that genus.

The form illustrated by Hill *et al.* (1969, Pl. SVI, fig. 9) as *Pilophyllum* sp. from the upper part of the Jack Limestone Member of the Graveyard Creek Formation, Broken River, North Queensland (? M.-U. Silurian, Hill *et al.*, 1969, p. 12) differs from *Pilophyllum* in lacking a septal stereozone and having a very pronounced axial vortex. It may be congeneric with a form described as *Tabulophyllum* ? *lowryi* Hill and Jell, 1970, from the Upper Devonian Napier Formation of the Canning Basin, Western Australia. As mentioned by Hill and Jell (1970, p. 66) this latter form probably represents a new genus.

The species composition of *Pilophyllum* is here taken to be: *P. keyserlingi* Wedekind, *P. manthei* Wedekind, *P. sayuhoense* Wang and *P. multiseptatum* (Strusz). Doubtfully included in the genus are *P. bimumurum* Sytova, “*Sinospongophyllum*” *planotabulatum* Yoh and “*S.*” *abrogatum* Hill.

Range. Wenlock of China; Ludlow of Gotland, Podolia and New South Wales; Upper Silurian of Tadzhikistan and Kazakhstan; Lower Devonian of ? Kazakhstan and ? Queensland; Middle Devonian of ? China.

Pilophyllum multiseptatum (Strusz, 1961)

Pl. XI, figs 4-6; Pl. XII, figs 1-3; Text-fig. 6

1961 *Nipponophyllum multiseptatum* Strusz, p. 346, Pl. 44, fig. 12; Pl. 45, fig. 9.*Material.* Holotype SUP 11099, limestone lens in Barnby Hills Shale, south of Bell River (Loc. 7?). Early Ludlow.*Diagnosis.* Fasciculate *Pilophyllum* with well developed peripheral stereozone, dissepiments weakly developed and only late in ontogeny and tabulae differentiated into axial and periaxial series.*Description.* Corallum fasciculate with lateral increase. Corallites sub-cylindrical with deep, steep-sided calice. Diameter of corallites ranges commonly from 12-14 mm.

Septal number ranges up to 64 in mature corallites with all septa set in a stereozone of lamellar sclerenchyme up to 1.5 mm wide. Sclerenchyme occurs thickly on corallite wall and to a lesser extent on the dissepimental surfaces (Pl. XI, fig. 5). Major septa are thin, extending 0.6-0.7 of corallite radius, interrupted peripherally late in ontogeny by lonsdaleoid dissepiments. Minor septa are up to 0.5 of length of major septa, generally not extending far beyond stereozone on corallite wall or dissepimental surfaces. They may show weak separation of trabeculae at their inner margins.

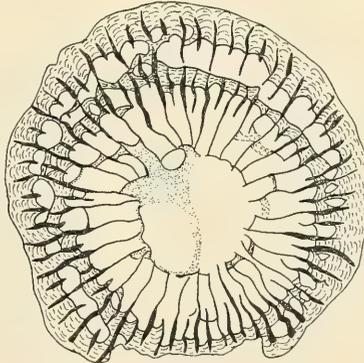


Fig. 6. *Pilophyllum multiseptatum* (Strusz), limestone lens in Barnby Hills Shale, Mumbil area. SUP 11099, holotype, transverse section, $\times 4$.

Dissepiments are lacking in early growth stages, septa extending uninterrupted from corallite wall (Pl. XI, fig. 4; Pl. XII, fig. 3). In late ontogeny, dissepiments developed in 1-2 rows, large, strongly elongate and steeply inclined with marked sclerenchymal coating. Tabularium width is approximately 0.7 of corallite diameter. Tabulae occur in two series: an outer, distally inclined series comprising closely spaced, incomplete tabulae and an axial series of widely spaced, mainly flat, complete tabulae.

Remarks. This form was originally included in the genus *Nipponophyllum* Sugiyama, 1940, by Strusz (1961) but differs from that genus in lacking discrete septal spines. Further thin sections prepared from the holotype material have confirmed the lamellar character of the septa. Unfortunately the longitudinal section of the holotype figured by Strusz (1961, Pl. 44, fig. 12) has been partially destroyed but an additional section figured herein (Pl. XII, fig. 2), although not as well oriented, confirms the character of the tabulae and dissepiments. The material listed as a paratype of this species (SUP 10299, Strusz, 1961, p. 346) is of a poorly preserved carinate form and would not appear to be conspecific with the above described species.

P. multiseptatum shows perhaps closest internal similarities to *P. weissermeli* Wedekind, 1927 (?=*P. keyserlingi*), from the Klinteberg Beds (Upper Wenlock-Lower Ludlow) of Gotland and Akkan Horizon (Upper Silurian) of Kazakhstan (Wedekind, 1927; Sytova and Ulitina, 1966). *P. multiseptatum* may be distinguished however, by its much smaller size, broader stereozone on the corallite wall and differentiation of the tabulae into two series.

P. multiseptatum also shows similarities to the type species of "*Sinospongyllum*", "*S.*" *planotabulatum* Yoh, 1937, from the Middle Devonian of China. Particularly comparable are the degree of peripheral septal thickening and the complete tabulae in the axial region. However, "*S.*" *planotabulatum* is a much larger, solitary form and has less development of peripheral, incomplete tabulae, the axial complete tabulae being more closely spaced.

Family STAURIIDAE Edwards and Haime, 1850

Genus PALAEOPHYLLUM Billings, 1858

1969 *Palaeophyllum*; Ivanovskiy, p. 80 (*cum syn.*)

1972 *Palaeophyllum*; Webby, p. 151

1972 *Palaeophyllum*; Merriam, p. 29

Type species. *P. rugosum* Billings, 1858. Lake St. John, Little Discharge, Quebec. Black River or early Trenton.

Diagnosis. (Modified from Hill, 1961, p. 4.) Corallum phacelo-ceriod. Corallites have narrow peripheral stereozone and lack dissepiments. Major septa are long and thin and minor septa are generally short. Tabulae are thin, commonly complete and arched, sometimes with axial depression.

Discussion. Ivanovskiy (1969) proposed that the known species of *Palaeophyllum* could be grouped into three broadly defined species: *P. thomi* (Hall, 1857); *P. fasciculum* (Kutorga, 1837) and *P. lebediensis* (Tcherepnina, 1960). The writer agrees with Webby (1972) that these three "species" may be better considered as species groups (or ? subgenera). *P. oakdalensis* sp. nov. described below, with well-developed minor septa and flattened tabulae, is representative of the *P. fasciculum* group, as suggested by Webby (1972).

Range. Lower Caradoc of Scotland, North America and New South Wales; Upper Caradoc of North America, ? Urals and ? south-west Siberia; Ashgill of Norway, Estonia, Urals, Siberian Platform, south-west Siberia, North America and ? China; Lower Llandovery of Estonia, Urals, Siberian Platform and ? North America; Upper Llandovery of Norway, Greenland and ? Siberian Platform; ? Late Wenlock of New South Wales; Late Wenlock-Ludlow of New York; Ludlow of ? California.

Palaeophyllum oakdalensis sp. nov.

Pl. XII, figs 4-8; Text-fig. 7

1961 *Palaeophyllum rugosum* Billings; Strusz, p. 341, Pl. 42, figs 7, 8, 15; Text-fig. 3.

Derivation of name. After the property of "Oakdale".

Material. Holotype SUP 74229 Catombal Park Formation, Oakdale Anticline, Mumbil area (Loc. 3). Paratypes SUP 10240, 10244-10246, 10248-10250, 74230-74235. Same horizon, Locs 3, 4, 5. ? Late Wenlock.

Diagnosis. *Palaeophyllum* with average corallite diameter 7 mm. Major septa extend to nearly 0.8 of corallite radius at maturity, minor septa generally 0.4 length of major septa. Peripheral stereozone well developed and major septa average 20 in number. Tabulae range in shape from flat to strongly arched, with gently arched types most common; spacing very variable.

Description. Corallum phaceloid. Increase is calicinal and parricidal, with four offsets from the one corallite being most common (Pl. XII, fig. 8). Possible lateral budding is also represented. Corallite diameter ranges from 6·5–8 mm in mature specimens with an average of 7 mm. Septa are of two orders, set in a narrow but clearly developed peripheral stereozone of lamellar sclerenchyme. This stereozone averages 0·1 of radius of corallite. Major septa are thin, tapering slightly towards axis. In early growth stages, major septa extend almost to corallite axis (Pl. XII, fig. 8), but in maturity they are somewhat withdrawn extending 0·7–0·8 of corallite radius (Pl. XII, fig. 5) and numbering 20–22. Minor septa reach 0·35–0·5 of length of major septa.

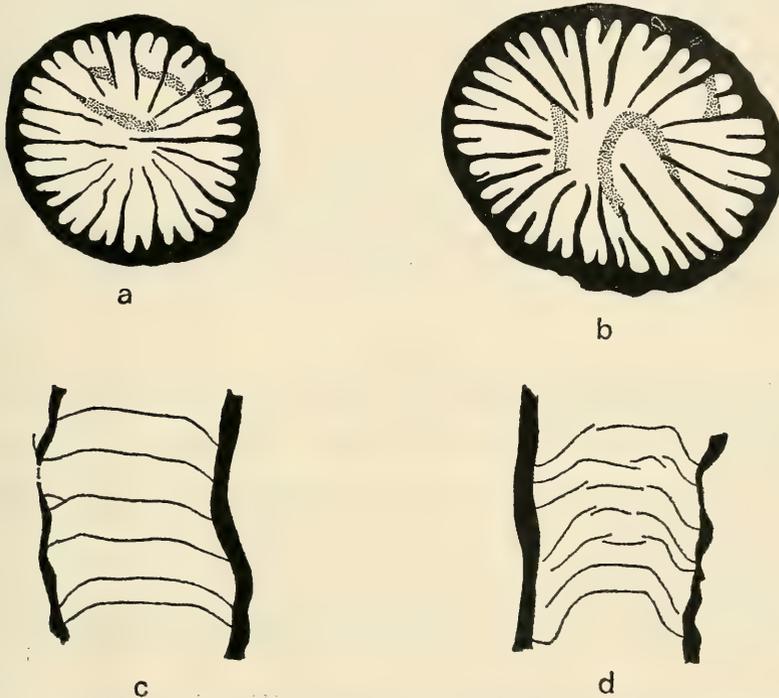


Fig. 7. *Palaeophyllum oakdalensis* sp. nov., Catombal Park Formation, Mumbil area. a. SUP 74233, paratype, transverse section of immature specimen, $\times 6$. b. SUP 74229b, holotype, transverse section of mature specimen, $\times 6$. c. SUP 74231b, paratype, longitudinal section showing most commonly observed tabular shape, $\times 4$. d. SUP 74230b, paratype, longitudinal section showing rarely developed highly arched tabulae, $\times 4$.

Tabulae are generally flat with weakly downturned edges. Degree of downturning is very variable, some barely showing this feature while others are markedly domed (Text-figs 7c, d). Tabulae are only rarely incomplete. Spacing of tabulae is quite variable. In a few examples they are closely spaced (0·1 mm) and grouped in series (Pl. XII, fig. 4) but in general they are evenly and widely spaced, average 0·8–1·2 mm. Axial depression of tabulae is very weak or more commonly absent.

Remarks. Strusz (1961) originally described this form as belonging to *P. rugosum* Billings, 1858, the Upper Ordovician type species from Quebec. However, from the descriptions of Hill (1961) it may be clearly distinguished from *P. rugosum* by having parricidal increase, longer minor septa and tabulae lacking a marked axial depression. Webby (1972, p. 152) also recognised the distinction of Strusz's form from the type species.

Species of *Palaeophyllum* have not been commonly recorded from the Silurian and the only forms of comparable age to *P. oakdalensis* are *P. multicaule* (Hall, 1852) redescribed by Oliver (1963), and *Palaeophyllum*? sp. G of Merriam (1972). *P. multicaule* is represented in the Lockport Dolomite (late Wenlock-late Ludlow) of Lockport, New York, and may be distinguished from *P. oakdalensis* in having smaller corallite diameter, longer major septa and shorter minor septa. *Palaeophyllum*? sp. G occurs in the Gazelle Formation (Ludlow) of the Klamath Mountains, California. It has flattened tabulae comparable to some specimens of *P. oakdalensis* but differs in having shorter septa, particularly in early growth stages (Merriam, 1972, Pl. 2, figs 9, 10). In its short septa (approximately 0.5 of corallite radius), *Palaeophyllum*? sp. G would appear to be intermediate in character between typical *Palaeophyllum* and *Pycnostylus* Whiteaves.

None of the previously described Australian representatives of *Palaeophyllum* (Webby, 1972) bear any close similarities to *P. oakdalensis*.

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EXPLANATION OF PLATES

PLATE VIII

Figs 1–5. *Holmophyllum colligatum* (Hill), Bowspring Limestone, Hatton's Corner, Yass district, AM 704, holotype, $\times 5$. 1–2. transverse sections. 3–5. longitudinal sections.

Figs 6–9. *Holmophyllum struszi* sp. nov., Catombal Park Formation, Oakdale Anticline, Mumbil area. 6. SUP 74220c, holotype, transverse section, $\times 4$. 7. SUP 10289, paratype, transverse section showing recrystallised septal spines, $\times 25$. 8. SUP 10289, paratype, transverse section, $\times 3$. 9. SUP 74220g, holotype, longitudinal section, $\times 3$.

PLATE IX

Figs 1–3. *Holmophyllum struszi* sp. nov., Catombal Park Formation, Oakdale Anticline, Mumbil area. 1. SUP 74220d, holotype, longitudinal section, $\times 4$. 2. SUP 74220k, holotype, longitudinal section, $\times 4$. 3. SUP 74220h, holotype, longitudinal section, $\times 4$.

Figs 4–7. *Holmophyllia maculosa* sp. nov., Catombal Park Formation, Oakdale Anticline, Mumbil area, $\times 5$. 4. SUP 40261d, holotype, longitudinal section. 5. SUP 40261e, holotype, longitudinal section. 6. SUP 40261e, holotype, longitudinal section. 7. SUP 40261a, holotype, transverse section.

Fig. 8. *Holmophyllia* cf. *simplex* (Lewis), Narragal Limestone, Mumbil area, $\times 3$. SUP 74228, tangential longitudinal section.

PLATE X

Figs 1–7. *Holmophyllia* cf. *simplex* (Lewis), Narragal Limestone, Oakdale Anticline, Mumbil area. 1. SUP 39184a, transverse section showing rhabdacanthine septa, $\times 25$. 2. SUP 39184c,

longitudinal section showing partially fused septal spines on corallite wall, $\times 25$. 3. SUP 39184c, longitudinal section, $\times 3$. 4. SUP 39184c, longitudinal section showing fused septal spines on corallite wall, $\times 25$. 5-7. SUP 39184a, transverse sections of different corallites, $\times 7$.

Figs 8-10. *Coronoruga dripstonense* Strusz, Narragal Limestone, Mumbil area, $\times 3$. 8. SUP 11103f, paratype, transverse section of early growth stage. 9. SUP 11103a, paratype, longitudinal section. 10. SUP 11212, paratype, longitudinal section showing sclerenchymal coating on tabulae.

PLATE XI

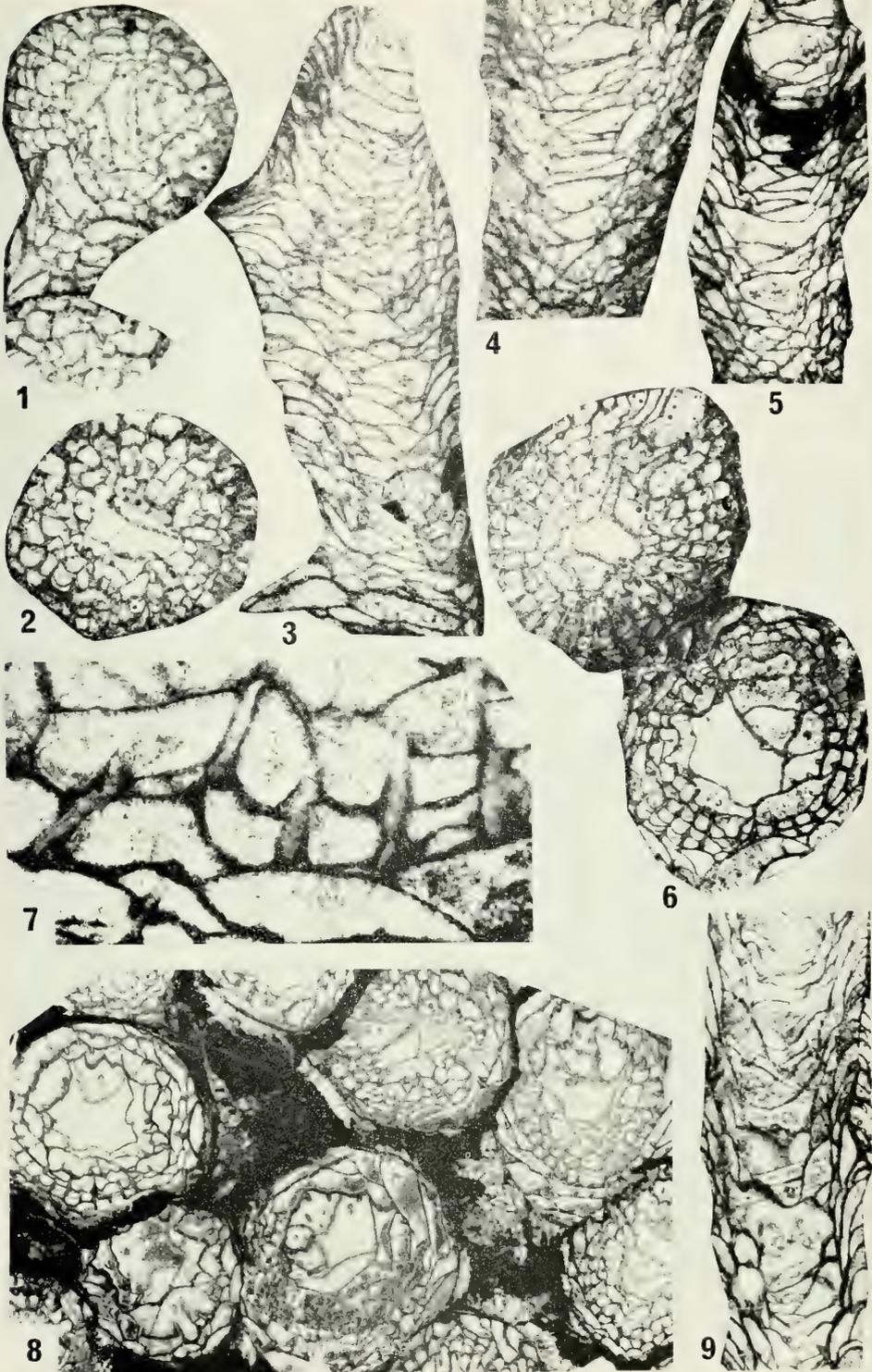
Figs 1-3. *Coronoruga dripstonense* Strusz, Narragal Limestone, Mumbil area, $\times 3$. 1. SUP 11215, paratype, transverse section. 2. SUP 11198a, paratype, transverse section. 3. SUP 11103b, paratype, longitudinal section showing sclerenchymal coating on dissepiments.

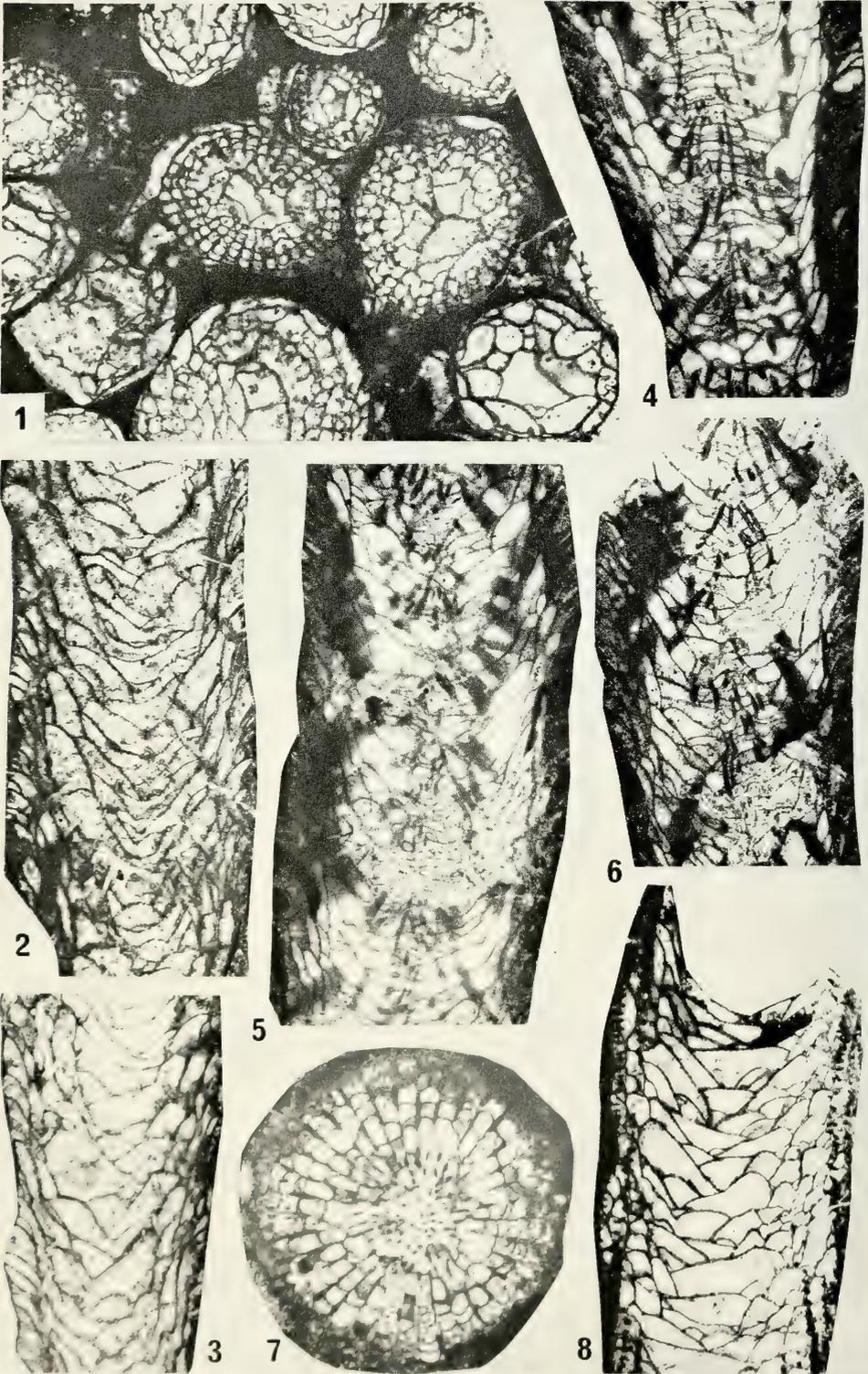
Figs 4-6. *Pilophyllum multiseptatum* (Strusz), limestone lens in Barnby Hills Shale, Mumbil area. 4. SUP 11099f, holotype, transverse section, $\times 4$. 5. SUP 11099c, holotype, longitudinal section showing lateral increase and sclerenchymal coating of dissepiments of incomplete corallite at right, $\times 3$. 6. SUP 11099h, holotype, transverse section, $\times 4$.

PLATE XII

Figs 1-3. *Pilophyllum multiseptatum* (Strusz), limestone lens in Barnby Hills Shales, Mumbil area. 1. SUP 11099g, holotype, longitudinal section, $\times 4$. 2. SUP 11099d, holotype, longitudinal section, $\times 3$. 3. SUP 11099i, holotype, transverse section of early growth stage, $\times 4$.

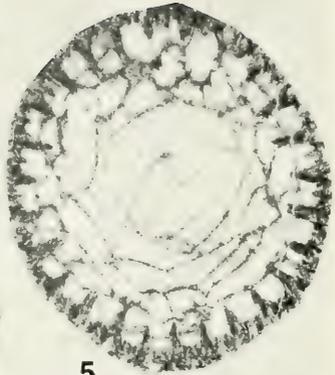
Figs 4-8. *Palaophyllum oakdalensis* sp. nov., Catombal Park Formation, Oakdale Anticline, Mumbil area. 4. SUP 74235, paratype, thin section (note variation in tabular spacing), $\times 3$. 5. SUP 74229a, holotype, thin section, $\times 4$. 6. SUP 74229e, holotype, longitudinal section, $\times 4$. 7. SUP 74229f, holotype, longitudinal section, $\times 4$. 8. SUP 74233, paratype, transverse section (note quadripartite offsets at right), $\times 4$.







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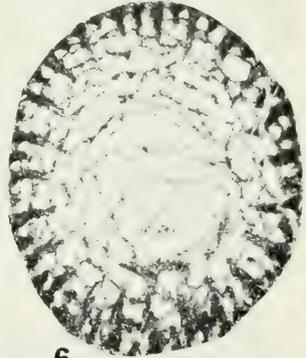
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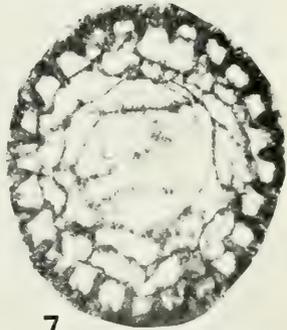
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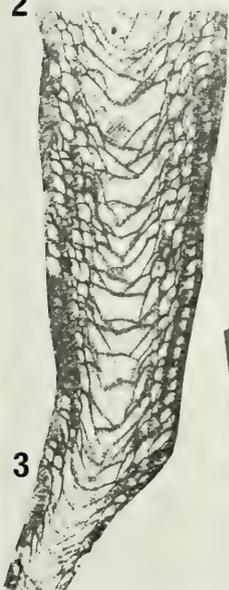
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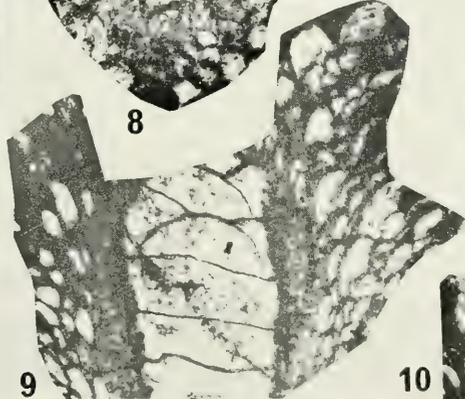
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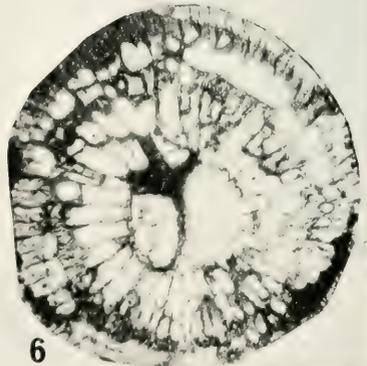
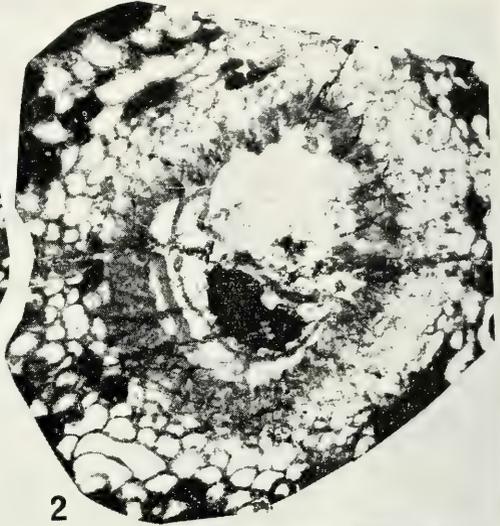
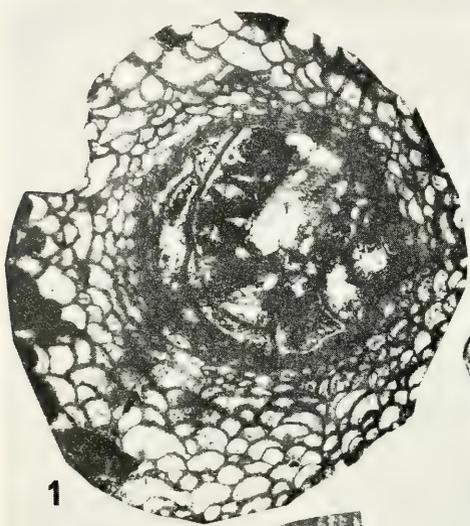
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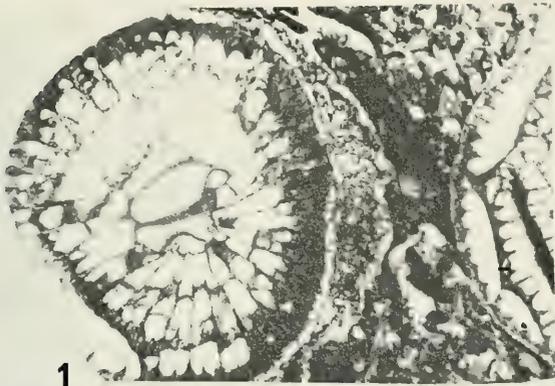


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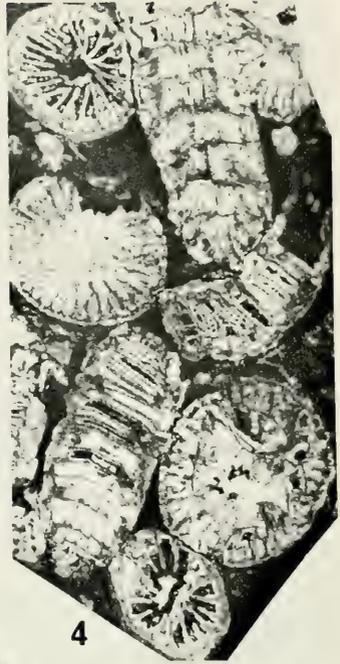


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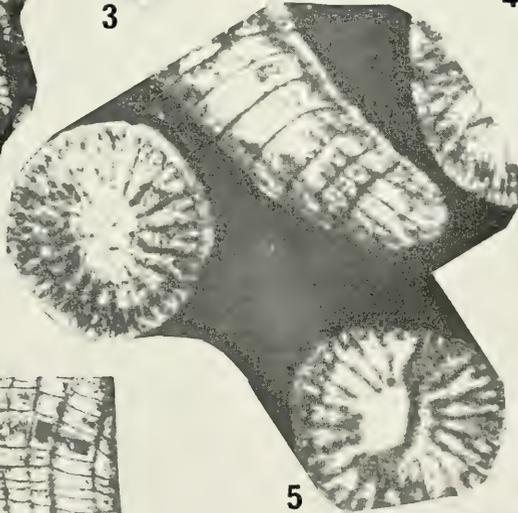
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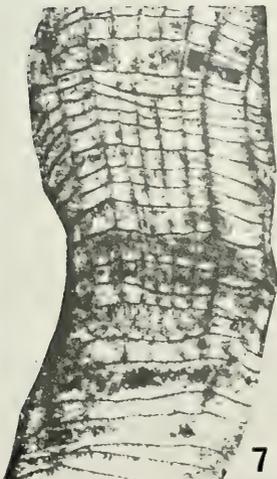
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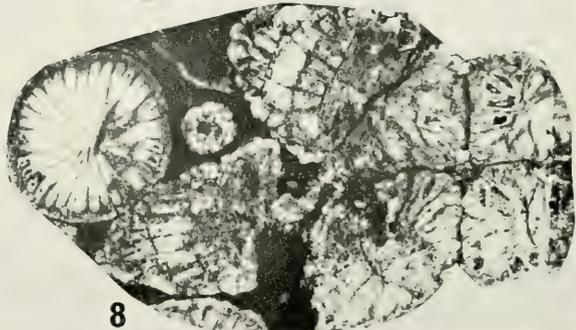
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8

NUCLEIC ACIDS IN CHLOROPLASTS OF A *CHLORELLA* SP.

A. R. PILLAY,* Y. T. TCHAN† AND K. Y. CHO‡

(Plates XIII and XIV)

[Accepted for publication 24th July 1974]

Synopsis

Nucleic acids in chloroplasts of *Chlorella* (NM1) are demonstrated by light and electron microscopy. The chloroplasts are positively stained by Feulgen stain. Electron microscopical examination shows fine filamentous fibrils in association with lamellar membranes and ribosomes. The fibrils are linear, single and double looped, and morphologically are not unlike that of DNA. They are distributed throughout the chloroplast matrix and tend to accumulate around the pyrenoid and in areas of low density between the chloroplast lamella. Polysomes are detected at these sites. The fibrils are not observed after treatment with deoxyribonuclease. It is concluded that these fibrils contain DNA and their significance is discussed.

INTRODUCTION

Biochemical studies indicate protein synthesis in the chloroplast as distinct from cytoplasmic protein synthesis (Kirk, 1964; Ray and Hanawalt, 1965; Smillie *et al.*, 1967; Selsky, 1967). Such findings agree with the cytological demonstration of RNA and DNA in chloroplasts of plants and algae (Ris and Plaut, 1962; Brawerman, 1962, 1963; Eisenstadt and Brawerman, 1964; Kislev *et al.*, 1965; Gunning, 1965; Sagen *et al.*, 1965). In *Chlorella* however, there is still no direct demonstration of DNA in the chloroplast although biochemical investigations strongly support its presence (Kirk, 1971). The present paper reports the location and morphology of DNA and RNA in the chloroplast of *Chlorella* (NM1) using light and electron microscopy.

MATERIALS AND METHODS

Organism and Growth Conditions

A species of *Chlorella*, isolated from a garden soil and designated NM1, was used.

Cells were grown in Erlenmeyer flasks in a defined mineral solution (Tchan, 1959) at pH 6.8 and aerated with CO₂-enriched air. The flasks were placed in a water shaker-bath at 28°C and illuminated by two (60W) incandescent lamps. The intensity of incident light on growth flasks was 50 lux. Samples were taken from two-day old cultures for cytological studies. Preliminary work indicated that the removal of starch grains from the cells was necessary to facilitate the detection of fine structure. This was achieved by keeping actively growing two-day old culture in the dark without agitation for 12 hours at room temperature (22°C).

Light Microscopy

Cells were fixed in alcohol-acetic acid (3:1) for 10 minutes. They were mounted on glass slides, washed with absolute ethanol and then brought to water

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through a graded series of alcohol. Some slides were treated for 15 minutes in N HCl at 60°C, and stained with Feulgen's reagent for 90 minutes in darkness. Other slides, after hydrolysis treatment, were stained with a Feulgen-fluorescent dye for 60 minutes in the dark. Control slides were stained without hydrolysis. All slides were washed in distilled water, and bleached in a mixture of sodium bisulphite: N HCl, and distilled water (1:3:3 w/v/v) for 10 minutes with two changes. The slides were washed with tap water and mounted in glycerine.

Preparations stained with the fluorescent dye were observed by phase contrast and fluorescence microscopy using a 100× oil immersion objective. Fluorescence illumination was provided by an illuminator equipped with a HB200 high-pressure mercury arc lamp and a 3 mm BG12 excitation filter, and K530 barrier filter. The phase and fluorescence images were recorded on Kodak Super XX film with an initial magnification of ×600 and a final enlargement to ×3,350.

Electron Microscopy

A. Cells were prefixed at room temperature in 2.5% glutaraldehyde in sodium cacodylate buffer (0.045M, pH 6.2) for two hours, washed in the buffer for 24 hours (three changes) and followed by:

- (i) post-fixation in 1% OsO₄ in Michaelis buffer (pH 6.0) overnight at room temperature (Pease, 1964). The cells were washed three times in a 3-fold dilution of the buffer and then suspended in a small amount of 1.5% agar (50°C); or
- (ii) post-fixation in freshly prepared 0.5% unbuffered KMnO₄ solution for 10 minutes then washed five times in a 3-fold dilution of Palade's (1952) acetate buffer (pH 6.2) and suspended in a small amount of 1.5% agar (50°C).

Digestion by Deoxyribonuclease

B. Cells were fixed in 10% formalin in veronal acetate buffer (Pease, 1964) (pH 6.2) for 10 minutes, washed in distilled water and digested with 0.001% deoxyribonuclease I (Sigma) in veronal acetate buffer at 40°C for four hours.

The control sample was incubated in buffer only. After treatment cells were prefixed in glutaraldehyde and post-fixed in potassium permanganate solution as in A (ii), above.

The small agar blocks from fixations A and B were stained with 0.5% uranyl acetate buffered solution for two hours. Dehydration was carried out at five-minute intervals in 30%, 50%, 70% and 80% ethanol followed by 10 minutes in 90% and two changes in 100% ethanol. The blocks were cut into approximately 2 mm pieces, infiltrated in three changes of araldite for one hour each and overnight at room temperature. Polymerisation was realised in fresh araldite at 60°C for 36–48 hours. Sections were cut on a Porter Blum ultra-microtome MT-2 using glass knives and collected in nitrocellulose coated grids. After staining with lead citrate (Reynolds, 1963), sections were examined and photographed with a Philips EM200 or a Siemens Elmiskop I operating at 60 or 80 kV.

RESULTS

Light Microscopy

— In Feulgen stained cells, the chloroplast gives a colour reaction of about the same intensity as the nucleus (Pl. XIII, Fig. 1). A comparison of the internal structures of cell shown by Feulgen-fluorescent staining with those observed in phase contrast microscopy (Pl. XIII, Figs 2 and 3) clearly demonstrated the presence of DNA positive sites in the chloroplasts.

Electron Microscopy

Pl. XIII, Fig. 4 shows the presence of starch around the pyrenoid and in areas between the lamellae of the chloroplast. Pl. XIII, Fig. 5 was printed for maximum contrast to demonstrate areas of low electron density. These areas are not bounded by membranes and contain fibrils (Pl. XIII, Fig. 5). They are present in the vicinity of the pyrenoid region and randomly distributed within the chloroplast (Pl. XIII, Fig. 5).

In OsO_4 fixed cells the low density areas contain conspicuous fine fibrils only prior to deoxyribonuclease treatment (Pl. XIII, Fig. 7; Pl. XIV, Fig. 1). These fibrils are removed after treatment by deoxyribonuclease (Pl. XIII, Fig. 6). At a higher magnification, unattached filaments, and numerous DNA structures attached to the lamellar membranes are well resolved in linear, single and double looped configuration.

In sections of chloroplasts a number of DNA-containing areas occur in the vicinity of the pyrenoid and between the lamellae (Pl. XIII, Figs 5 and 7; Pl. XIV, Fig. 1). Their distribution is much more conspicuous than that reported by Ris and Plaut (1962) for *Chlamydomonas*. Unlike the brown algal (Gibbs, 1967, 1968; Bisalputra and Burton, 1969; Bisalputra and Bisalputra, 1969) they lack regular patterns.

Ribosomes and polyribosomes are frequently seen in close proximity or adhering to fibrils near the lamellar membranes. Free ribosomes are in the vicinity of pyrenoid and in the stroma regions between the lamellae (Pl. XIV, Figs 1 and 2).

DISCUSSION

Direct fixation with OsO_4 or KMnO_4 usually fails to preserve adequately the fine structures within the chloroplast (Gunning, 1965). KMnO_4 is reported to extract RNA but stabilises DNA as a branching network of fibrils (Luft, 1956; Bradbury and Meek, 1960; Nass and Nass, 1963; Nass *et al.*, 1965). OsO_4 can also result in leaching of proteins. It is not clear whether DNA fibrils are restricted to areas of low electron density in the chloroplast or more widely dispersed and obscured by ribosomes. It is known that direct KMnO_4 fixation removes ribosomes (Hayat, 1970). The present study shows that KMnO_4 could be used as a suitable post-fixative after the stabilisation of RNA and proteins by gluteraldehyde.

The absence of fibrils in the low density areas of the ground substance in the chloroplast after deoxyribonuclease treatment strongly suggests that these fibrils contain DNA, and this is in accord with the appearance of the chloroplasts before treatment and the positive Feulgen staining reaction (Pl. XIII, Figs 1, 2 and 3). The disappearance of ribosomes and the preservation of fibrils by KMnO_4 fixation also lends further support.

CONCLUSION

The present cytological investigation clearly demonstrated the presence of DNA in chloroplast of *Chlorella* (NM1). It exists as a number of short single units (Pl. XIV, Fig. 2). They are not restricted to the low electron density areas but are also found in electron dense areas where their presence may sometimes be obscured by ribosomes. This suggests a wider distribution of the DNA chloroplast. However, a few areas containing DNA appear to be randomly distributed through the chloroplast matrix and around the pyrenoid region. These areas may represent sites of greater activity in the chloroplast. Thus the early biochemical evidence is now supported by direct cytological observation.

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EXPLANATION OF PLATES

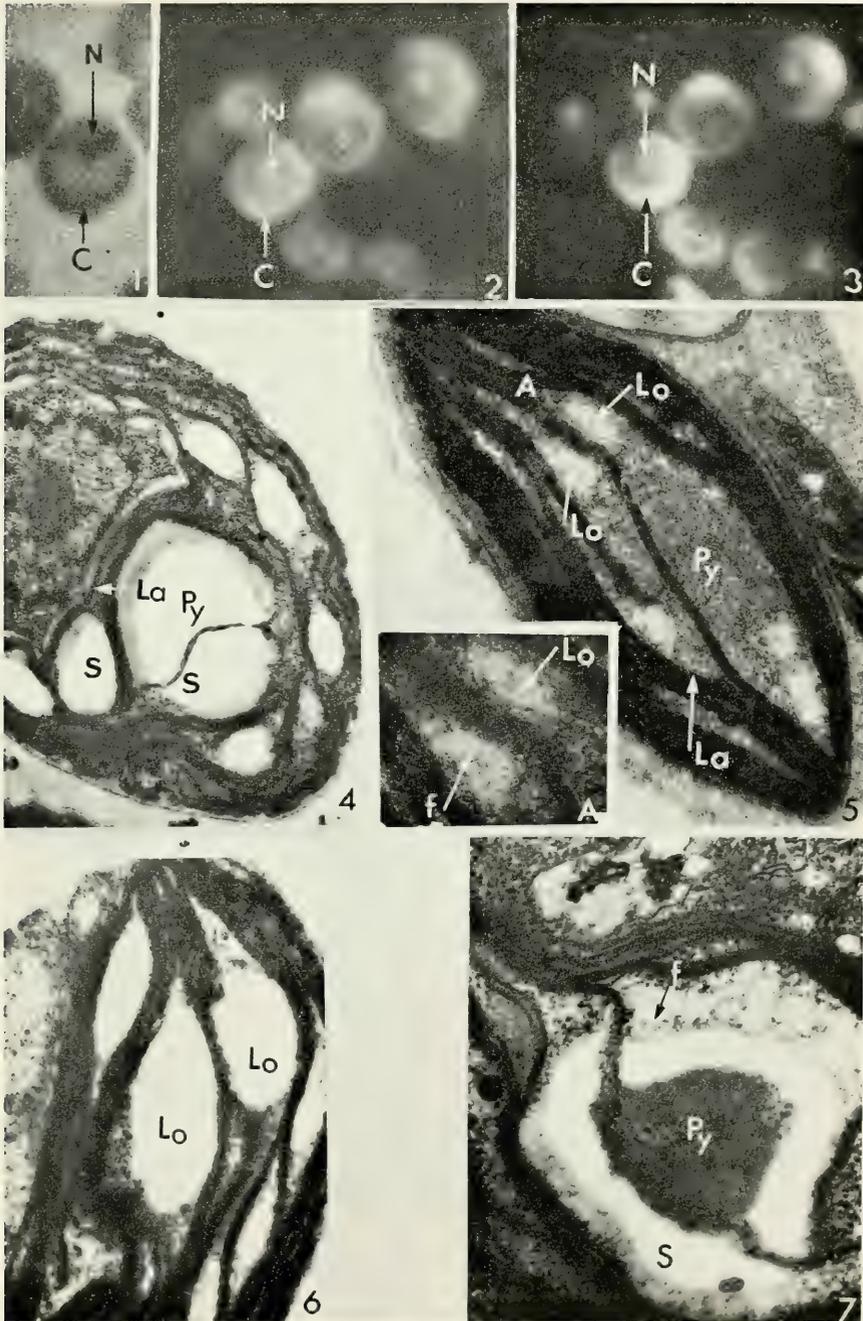
PLATE XIII

Fig. 1. Feulgen stained *Chlorella* NMI cell, showing nucleus (N) and chloroplast (C). $\times 3,350$.

Fig. 2. Feulgen-fluorescent dye stained *Chlorella* NMI cells examined by phase contrast microscopy. Chloroplast (C), nucleus (N). $\times 3,350$.

Fig. 3. The same cells as in Fig. 2 examined by fluorescent microscopy. Note fluorescence in regions identical to those identified as chloroplast (C) and nucleus (N) in Fig. 2. $\times 3,350$.

Fig. 4. *Chlorella* NMI. Note starch (S) in pyrenoid area (Py) and starch granules (S) scattered in areas between lamellae (La) of chloroplast. Glut. OsO₄. $\times 22,100$.



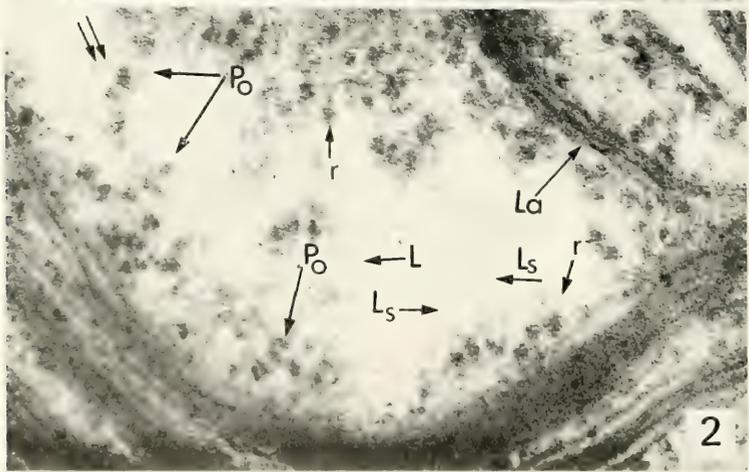
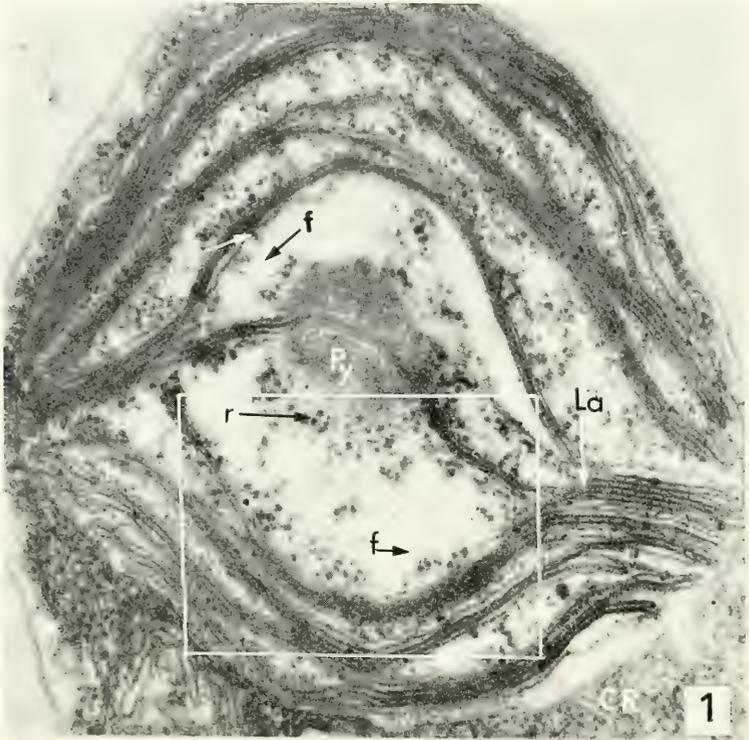


Fig. 5. Cell printed for maximum contrast. Low electron dense areas (Lo) around the pyrenoid (Py) and between lamellae of chloroplast. Glut. KMnO_4 . $\times 24,750$. Inset A shows DNA fibrils (f) in low density areas. Glut. KMnO_4 . $\times 60,000$.

Fig. 6. Cell printed for maximum contrast. Note absence of fibrillar material in low density areas (Lo) after deoxyribonuclease digestion. Glut. KMnO_4 . $\times 29,700$.

Fig. 7. Portion of chloroplast showing pyrenoid area. Note starch sheath (S) and fibrils (f) around pyrenoid (Py). Glut. OsO_4 . $\times 53,000$.

PLATE XIV

Fig. 1. Section of *Chlorella* NMI showing chloroplast. Fine fibrils (f) and ribosomes (r) can be seen in the organelle. White arrow indicates attachment of DNA fibril to lamellae membrane: Pyrenoid (Py), lamellae (La) and cytoplasmic ribosomes (CR). Glut. OsO_4 . $\times 53,000$.

Fig. 2. Magnified portion of Fig. 1. Linear DNA fibrils (double arrows), single loop (L) and double loops (Ls), lamellar membrane (La), polyribosomes (Po) are found close to DNA fibrils. Glut. OsO_4 . $\times 105,000$.

NOTES AND EXHIBITS

Dr. D. McAlpine exhibited specimens of *Boea hygrosopia* (Family Gesneriaceae), a rain forest plant from the Atherton Tableland, Queensland, which shows remarkable drought adaptation. The plant becomes shrivelled and dessicated in the dry season but is totally reconstituted after a few hours' submergence in water. The plant is closely related to the familiar African violet.

Dr. I. V. Newman presented a note on the journey made by George Caley in February 1805, from Pennant Hills to Narrabeen and back. Caley was collector for Sir Joseph Banks from April 1800 to May 1810. Dr. Newman exhibited a copy of Caley's own map of the journey and a route plan of it, drawn on a current road map of the area, calculated from Caley's original description and map (both of which are housed in the Mitchell Library, Sydney). Caley's near passage on this journey to an unnamed creek in Wahroonga has provided support for a recommendation that the creek be named "Caley's Creek" and that a proposed recreational area nearby be named "Caley's Common".

Professor T. G. Vallance (President) exhibited two copies of the Society's first publication; both are preserved in the library at Science House. Each bears on its title-page: *The Linnean Society of New South Wales. / = / Sydney: / F. Cunninghame & Co., Steam Machine Printers, 186 Pitt Street. / - / 1874.* Both copies measure 195 × 130 mm and have pp. 10 (the last blank) with the sheets sewn, the last leaf being tipped-in. The issue with printed blue paper wrappers agrees with that described as 11655c in Ferguson: *Bibliography of Australia* (Vol. VI, Sydney, 1965); the other, with printed yellow paper wrappers, is otherwise identical. The text lists, first, Officers and Council (p. 3), then, 107 names of Original Members (pp. 3-6) and, finally, the Rules (pp. 7-9) of the new Society. Both copies have been extensively annotated and corrected by hand, perhaps by way of preparation for the second edition, dated 1876, which is to be found in some bound copies of the first volume of our *Proceedings*.

As the official records of the Society's early years were lost in the Garden Palace fire (22 September 1882) it does not appear possible to discover the actual date of these first publications. Indeed, despite the 1874 imprint the pamphlets may not have been issued until early in the following year. We know that the committee appointed at the inaugural meeting of the Society (29 October 1874) to prepare a draft set of Rules completed its work promptly as the Rules were adopted on 5 November 1874. But according to J. J. Fletcher (*Macleay memorial volume*, 1893, p. XXXI) the first Council was not elected until 13 January 1875. Dr. A. B. Walkom, however, in the Society's Jubilee Publication (*Historical notes of its first fifty years*, Sydney, 1925) does not refer to this meeting and lists the first councillors as having been elected from 1874. Whether printed late in 1874 or early in 1875, these pamphlets survive as a previous record of the Society's membership in its foundation year. That the present enrolment is only about three times greater than it was one hundred years ago is a sobering fact.

Again referring to our centenary, Professor Vallance reminded members of the recent gift from the Linnean Society of London of a splendid engraving after H. W. Pickersgill's portrait of Robert Brown. The engraving is currently on display with selected material from our archives in the galleries of the Library of

New South Wales. By way of celebrating this important donation as well as the bicentenary of Robert Brown's birth (21 December 1773), the President commented briefly on Brown's great contribution to Australian science begun while naturalist aboard H.M.S. *Investigator* under the command of Matthew Flinders. This fruitful association is commemorated in a set of the two-volume work of Flinders: *A voyage to Terra Australis* (London, 1814) owned by the Linnean Society of New South Wales. The half-title leaf in Volume I of this set bears the inscription: To/Mr. John Sangster/from His Relation & Friend Robert Brown/a member of the Voyage. Below, in pencil, is the date 1857, the year before Robert Brown's death. These volumes were presented to the Society in 1887 by Mr. Sangster; the donation is acknowledged in our *Proceedings* (Vol. 2, 1887, p. 454) where, strangely, no mention is made of the distinguished provenance. The work was transferred recently, on extended loan, to the Rare Books department of the University of Sydney Library; its brief return for exhibition at this meeting has been effected with the ready cooperation of the University Librarian.

Mr. G. P. Whitley exhibited (by permission of the Curator of the Macleay Museum, University of Sydney) photographs of the Whistle Insect. The Whistle Insect is the oldest known specimen in the Macleay Museum, being labelled "A curious insect from Barbary, the only one of its kind in England. Geo. Edwards, 1756".

A picture of a "Whistle Insect" in the anonymous *Naturalist's pocket magazine* (Vol. 2, 1799, no pagination, plates unnumbered) was recognised as a depiction of the "curious insect" specimen in the Macleay Museum. The picture is evidently a copy of one of three figures of the Macleay Museum specimen found in George Edwards's *Gleanings of natural history* (Vol. 2, 1758: 160, pl. 285, figs 3-5), a rare book in the collection of the National Library, Canberra. Edwards's figures were named *Gryllus spinulosus* by Linneaus in 1763, so the specimen, brought to Sydney by Alexander Macleay in 1825, is obviously the holotype of that species, which has been referred to the genus *Eugaster* by Kirby, 1906 (Orthoptera: Acridoidea).

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